

> **INVENTING IMMORTALITY**
Is death a disease we can cure?

> **CLOUD CITIES**
How to colonise Venus without touching the ground

> **FIX THE PLANET**
The technology that can end the crisis.

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PLUTO

A NEW WORLD
WHY IT'S MORE AMAZING
THAN WE EVER IMAGINED

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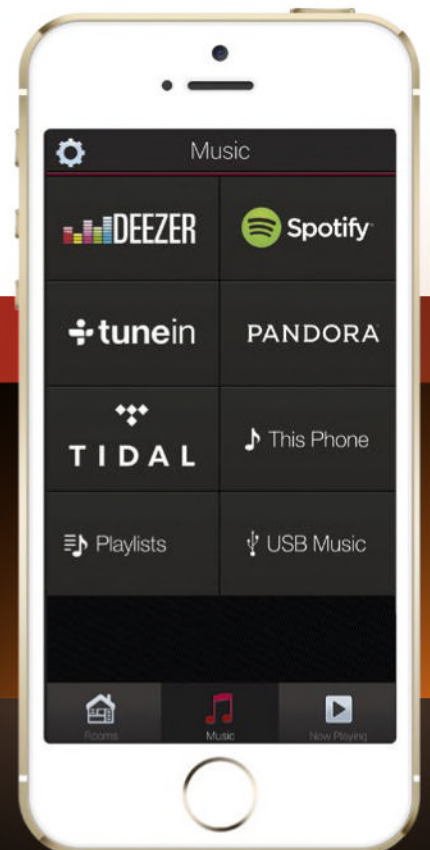
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THE SCIENCE ILLUSTRATED CREDO

We share with our readers a fascination
with science, technology, nature, culture
and archaeology, and believe that through
education about our past, present and future,
we can make the world a better place.

Check your sums... or don't?



While the new images of Pluto streaming back from New Horizons are amazing, what's truly amazing to me is that we owe almost all our knowledge and understanding of that tiny distant world to maths. And, as it turns out, wrong maths.

A quick recap: the five classical planets - Mercury, Venus, Mars, Jupiter and Saturn - have been known since humans first looked up. You can see all these planets with the naked eye. After we developed a theory of gravity, it became apparent that Saturn's orbit was being affected by another planet. Then William Herschel peered through telescope to confirm the existence of Uranus in 1781.

As we came to understand Uranus' orbit, again it seemed like something was affecting it - another, large planet. Then, on 23 September 1846, something amazing happened. Johann Galle discovered Neptune, pinpointing the distant world within a single degree of where French celestial mathematician Urbain Le Verrier predicted it would be. Neptune remains the only planet discovered using pure maths, rather than empirical observation.

Pluto, not so much. Again, mathematics showed Neptune's orbit was being perturbed by something, another object exerting a detectable gravitational pull on the gas giant. In 1906 Percival Lowell (the man who thought there were canals on Mars) began and funded a search for "Planet X". Maths told astronomers more or less where to look, but the relative tininess of Pluto (about 2400 km across) made it much harder to spot than Neptune (about 49,000 km across).

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In fact two photographs of Pluto were taken in 1915, but nobody recognised them as such. A 23-year-old astronomer named Clyde Tombaugh spent nearly a year comparing photos to see if a tiny point of light had shifted between pairs of shots - a sure sign of an orbiting planet. He confirmed Pluto on the 18th of February, 1930.

The discovery of Pluto was an amazing triumph... but here's the thing. Lowell and others thought it must be there because of irregularities in Neptune's orbit. But in fact, those "irregularities" had nothing to do with Pluto. They had to do with the fact that astronomers had made an error in calculating Neptune's mass. This error would not be corrected until the 1980s, when Voyager 2 flew by the planet.

Think about this for a minute. Long-ago astronomers make a mistake, assume a planet will be there even though, if they'd had the correct data, they would never have suspected this. Then a young man spends untold hours poring over photographic plates looking for a planet that, again, has no mathematically-backed evidence of existing... and he finds one.

Think that's a wild coincidence? How about this: in 1978, a US Navy astronomer named James Christy noticed a recurring bulge in the incredibly low-detail photographs of Pluto and surmised that it must be a moon. It was: he'd discovered Charon. But its existence was only confirmed when Pluto entered a specific part of its 248-year-long orbit where the Pluto-Charon system could be seen edge-on by Earth. Just 48 years after the dwarf planet's discovery.

That's what they call cosmic serendipity. Or perhaps just dumb luck.

Anthony Fordham

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THINGS WE LEARNED IN THIS ISSUE

- + We can **FIX THE PLANET** if we put our technology to good use.
- + Humans may one day **LIVE FOREVER** but will we still be human when we do?
- + Bugs fall victim to **TERRIFYING PARASITES** that use custom viruses to control their minds. Ugh!
- + Elsewhere in space **THE ROSETTA PROBE** continues to do amazing science and discover new things about comets.



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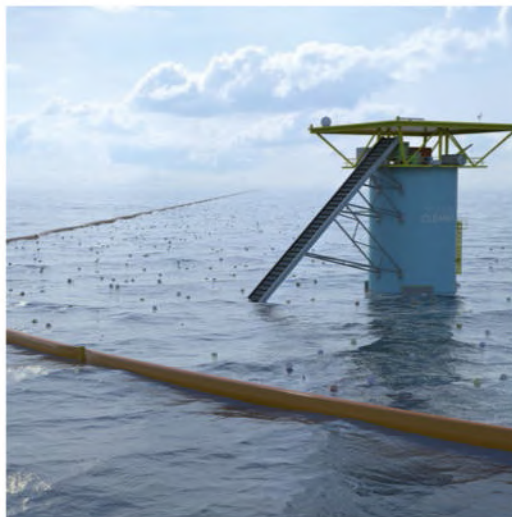
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FIX THE PLANET

We invented technology to save ourselves from the planet. Now, we can use technology to save the planet from ourselves.



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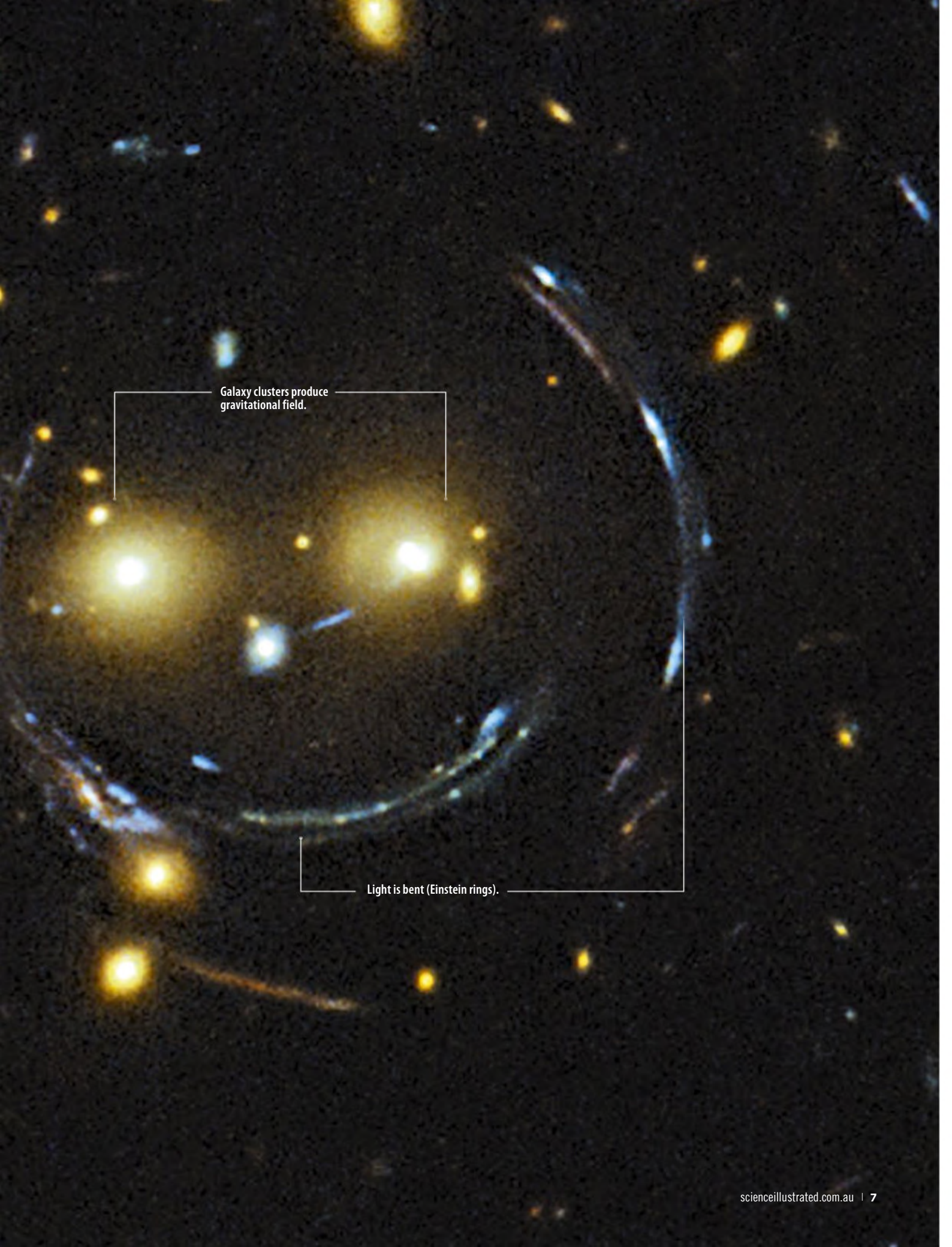
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↓ EINSTEIN RING SMILES AT US FROM SPACE

The huge mass of two galaxy clusters produces a powerful gravitational field, which makes the light of a remote light source bend. So, the galaxy clusters function like a gravitational lens, enabling scientists to study remote objects. When the gravitational lens and the light source are in line with the viewer, the bent light is observed as an Einstein ring. The smiling face was spotted by an amateur astronomer on an image taken by the Hubble space telescope.

ESA & NASA



Galaxy clusters produce
gravitational field.

Light is bent (Einstein rings).

Editors: Karine Kirkebeek

HUGE MAGMA CHAMBER FOUND UNDER VOLCANO

Yellowstone could be even more dangerous and destructive than we thought...

GEOLOGY Deep below the Yellowstone supervolcano in Wyoming, USA, scientists from the University of Utah have discovered a huge magma chamber. The chamber is located 20-45 km below the surface and is so huge that it contains no less than 46,000 km³ of magma – that's enough molten rock to fill up the 350-km-long Grand Canyon 11 times.

The new chamber is 4.5 times more massive than the reservoir above it – about 10 km below the dormant Yellowstone volcano – which seismologists have studied for some time.

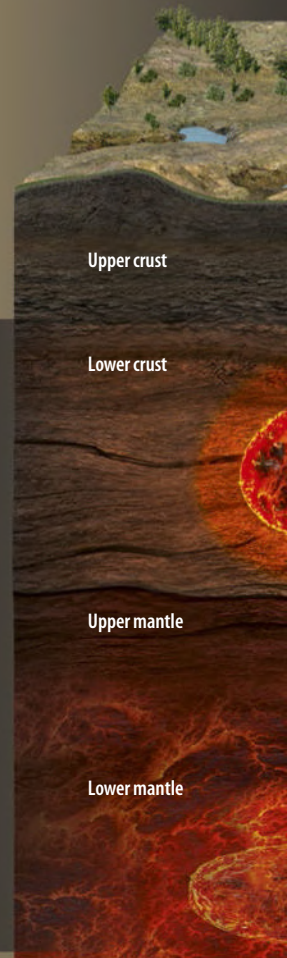
The huge chamber means that there is a direct connection from Earth's interior to the known upper magma chamber, and that explains how the volcano has previously been able to explode into an extreme eruption, during which so much volcanic material was ejected that it affected both the climate and life across the entire planet. According to scientists, the supervolcano has erupted three times. The first eruption took place 2.1 million years ago, the second one 1.3 million years ago, and the most recent and violent one happened 640,000 years ago.

Three chambers

Yellowstone's topography and the new magma chamber has been mapped out by using seismic measurements. The chamber links the known magma chamber at the top with liquid magma from Earth's mantle.

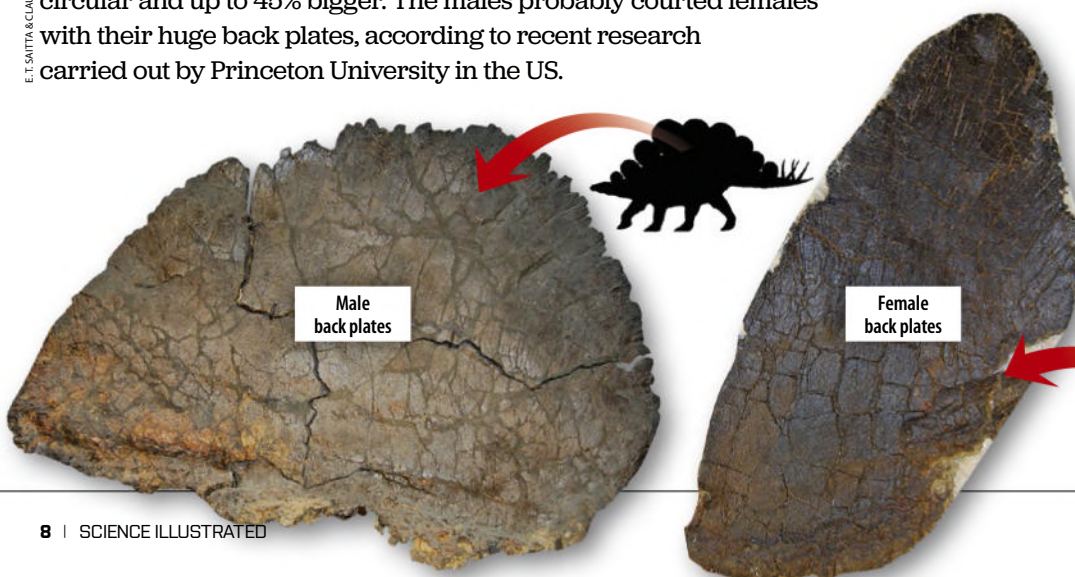
GLOSSARY

Supervolcano: A volcano that is able to eject at least 1,000 km³ of material during an eruption. There are only a handful of these on Earth.



MALES SHOWED OFF THEIR BACK PLATES

Female stegosaurus had pointed back plates, while the males' plates were more circular and up to 45% bigger. The males probably courted females with their huge back plates, according to recent research carried out by Princeton University in the US.



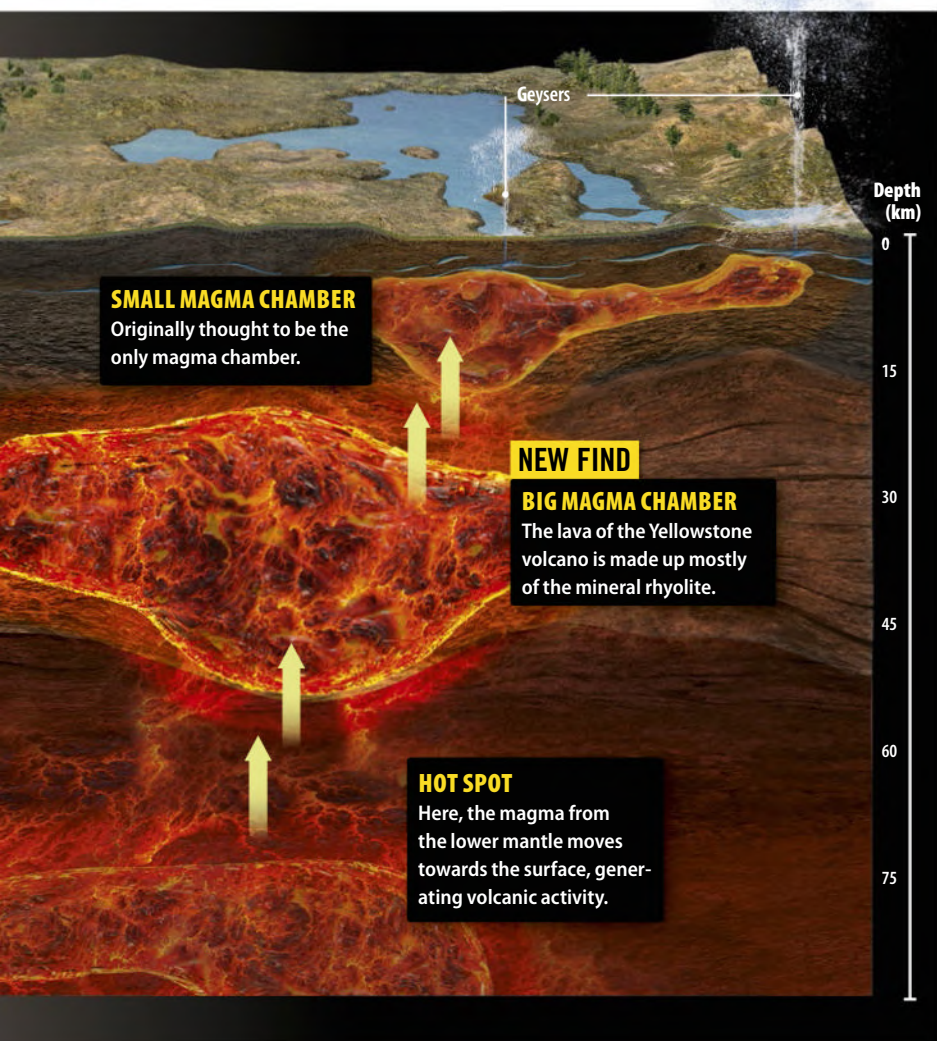
NEWS FLASH!

ANTS MANAGE WELL IN SPACE

A group of ants have been to the International Space Station (ISS), so scientists could study their reaction to weightlessness. They did very well: the ants quickly oriented themselves in their container, and began exploring the new territory.

647,250

trees have been planted in Ecuador in an effort to boost nature. It is the first time that so many trees have been planted at the same time.



CLAUS LUNAU



A camera analyses facial and eye movement, and predicts the driver's next move.

CAMERAS PREVENT CAR ACCIDENTS

TECHNOLOGY Scientists from Cornell and Stanford Universities in the US have developed a new monitoring technology, Brain4Cars, which can prevent accidents. The system includes a camera that analyses the driver's facial expressions and body language. Based on this, it can calculate the driver's next move. The analysis is combined with data about the surroundings and traffic supplied by external sensors. In case of any danger, the driver is alerted – either by light, sound, or vibrations in the steering wheel or the seat.

SHUTTERSTOCK

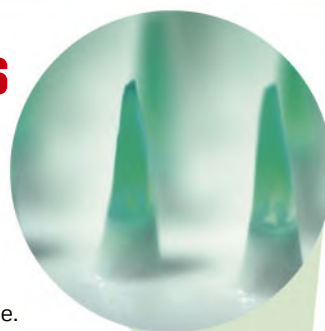
PATCH TO REPLACE INJECTIONS

MEDICINE A new invention may give a painless alternative to the traditional measles vaccination. Scientists from the Georgia Institute of Technology in the US have developed a vaccination patch that could replace injections as soon as 2017. As well as being painless, this method of vaccination doesn't need sterilisation, or highly trained medical staff to administer.

The patch, which measures 1 cm², is equipped with 100 microscopic needles made of polymers and sugar. As the patch is placed on the skin, the needles disintegrate, releasing the vaccine.

The patch is good news for

vaccination programmes in the third world, as it takes up very little space and can easily be carried to even the remotest regions of the world – and because the patch is easy to use for health staff and easily disposable after use.



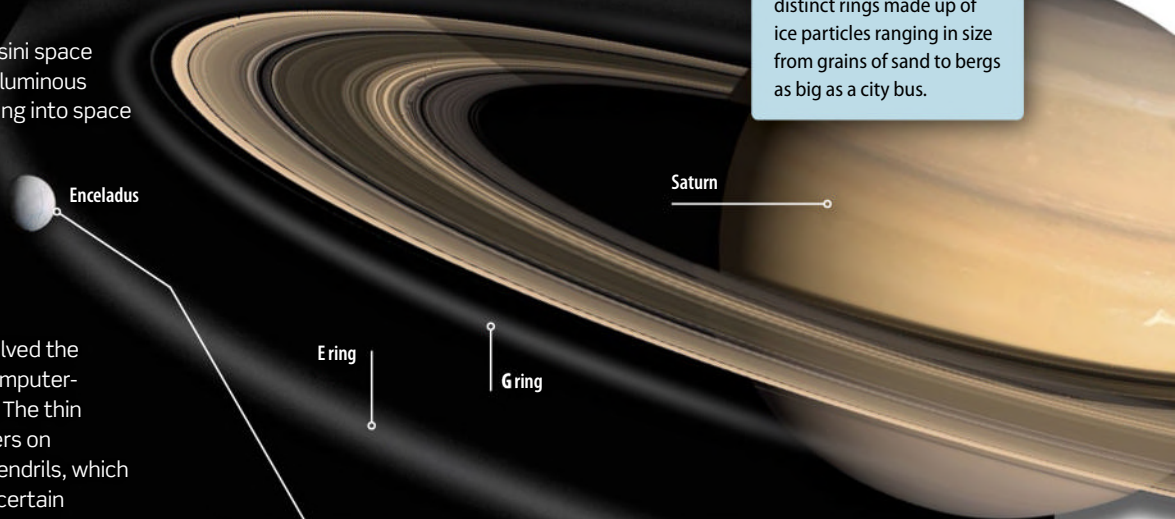
The vaccination patch's 100 microscopic needles inject the vaccine without causing pain.

GEORGIA INSTITUTE OF TECHNOLOGY

THE MYSTERY OF A WEEPING MOON

Tendrils protruding from Enceladus consist of microscopic ice particles.

ASTRONOMY In 2006, the Cassini space probe observed mysterious, luminous tendrils of ice particles winding into space from Saturn's moon Enceladus. Ever since, astronomers have wondered what caused the odd phenomenon, and now, scientists from the Space Science Institute in Boulder, Colorado, have solved the mystery by analysing and computer-processing Cassini's images. The thin tendrils originate from geysers on Enceladus' south pole. The tendrils, which can only be observed under certain lighting conditions, stretch tens of thousands of kilometres from the moon's surface into Saturn's E-ring - the ring in which Enceladus is orbiting. The scientists have calculated that the smallest ice particles have a diameter of approximately one millionth of a metre - or just 0.0001 cm. The discovery strengthens the hope of finding life on the small moon.

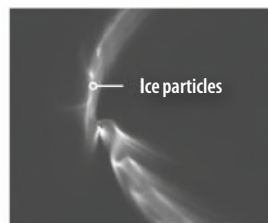


Facts about Saturn

TYPE: Gas giant.

MOONS: 60 (identified).

RINGS: Saturn has 7 distinct rings made up of ice particles ranging in size from grains of sand to bergs as big as a city bus.



Computer reveals source

The Cassini probe took the first picture of the Enceladus tendrils in 2006 at a distance of 2.1 million km. Scientists used a computer to process and analyse the image, only to discover that the mysterious tendrils are made up of ice particles.

The glasswinged butterfly's wings consist of column-shaped nanostructures of different heights, making the wings transparent.



BUTTERFLIES WEAR INVISIBILITY CLOAKS

ZOOLOGY When the glasswinged butterfly flies, you can only see the black contours of its wings, which are otherwise transparent. But scientists from the Karlsruhe Institute of Technology in Germany have found the insect's secret. The wing surface turns out to be studded with irregular, column-shaped nanostructures of different heights, and due to

these, only 2 % of the light is reflected. The rest passes directly through the wing.

The wings make the butterfly almost impossible to target and catch and so, they make up an efficient defence against predators. Scientists hope that the discovery can pave the way for non-reflecting displays for mobile phones and other gadgets.

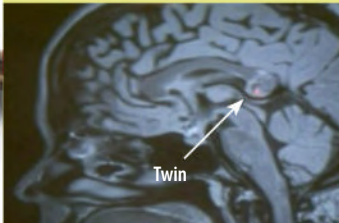
According to a study, men are more willing to take risks than women due to poorer judgment.

STRANGE

– BUT TRUE!

Woman carried twin in her brain

An American woman thought that she was to have a brain tumour removed, but after the surgery, she was told that the tumour was an embryonic twin. The tumour, including bones, teeth, and hair, is a very rare phenomenon.



YAMINI KARANAM

Dog eyes trigger love hormone

Humans cannot resist puppy-dog eyes, because they trigger the release of the oxytocin love hormone in our brains. We're programmed to respond to large, moist, soft-looking eyes. The hormone works best when parents look at their children, helping them to develop close bonds.

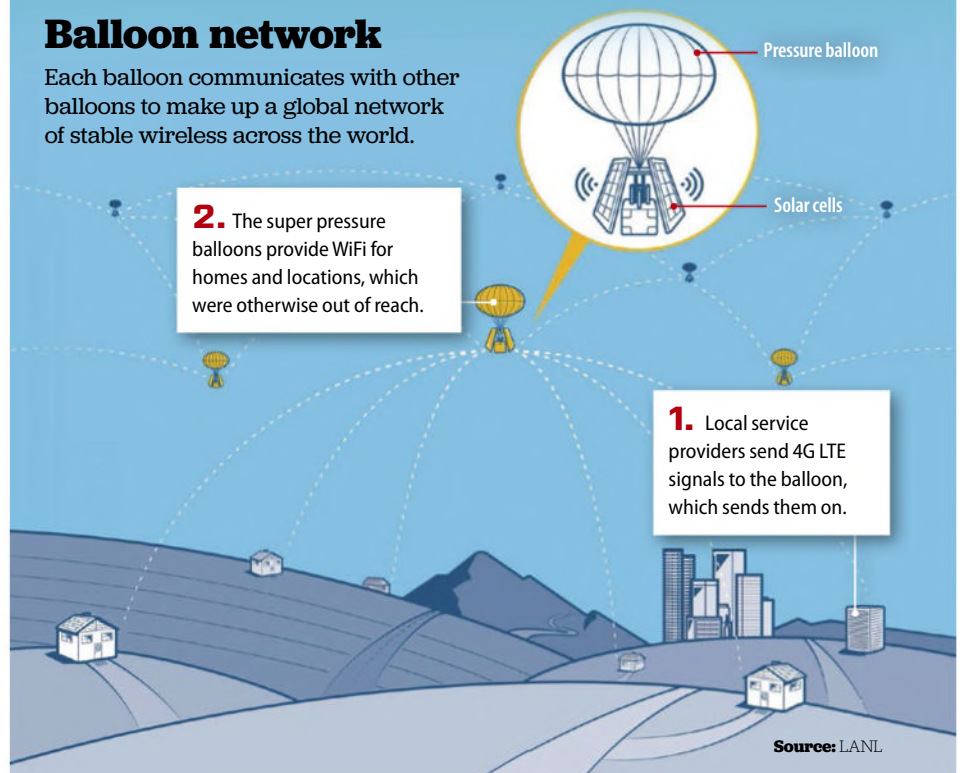
BALLOONS ENSURE STABLE WIFI

TECHNOLOGY Only half the world's population has cheap Internet access, but Google intends to change that with Project Loon. A global network of thousands of 12-m-high balloons full of electronics and

solar cells will float at an altitude of some 20 km to provide wireless broadband to even the remotest regions of the world. By the end of 2015, Google expects to have launched 100 high-tech balloons.

Balloon network

Each balloon communicates with other balloons to make up a global network of stable wireless across the world.



PIRATE TREASURE FOUND IN WRECK

American adventurers believe to have found a silver treasure, which once belonged to the notorious Scottish pirate William Kidd, who spread terror on the seas in the late 1600s. The treasure was discovered in a wreck off a small island near Madagascar. The ingot was probably cast in Bolivia.

AP/SCIENCE



NEWS FLASH!

ROBOTS TO LEARN FROM CHILDREN

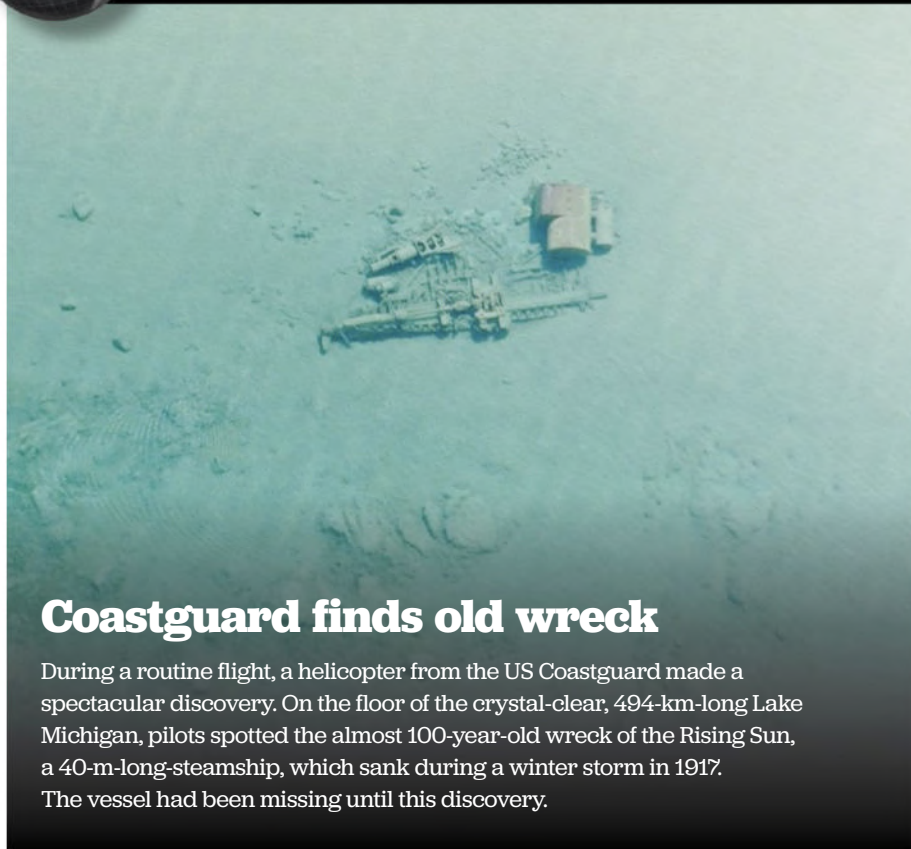
According to an experiment, children become more interested and develop higher self-esteem by being teachers. In the experiment, small robots were their students.

China intends to build the world's biggest airport, in Beijing. It will be 700,000 m², and open in 2018.



LOCAL FOCAL POINT

Lake Michigan, USA



Coastguard finds old wreck

During a routine flight, a helicopter from the US Coastguard made a spectacular discovery. On the floor of the crystal-clear, 494-km-long Lake Michigan, pilots spotted the almost 100-year-old wreck of the Rising Sun, a 40-m-long steamship, which sank during a winter storm in 1917. The vessel had been missing until this discovery.

US COAST GUARD



CHIMPS WATCH THEIR STEP

A team of French scientists has observed the way in which Ugandan chimps behave when they are about to cross a busy road on the outskirts of the jungle.

Much to the surprise of the scientists, the chimps are able to remain safe in traffic. Nine out of ten times, the monkeys look in one or both directions before running across the road. According to scientists, the fact that the monkeys often run rather than walk shows they can anticipate a car may come, and that cars are dangerous.

SHUTTERSTOCK



The water in the bag is sucked out and heated inside the machine, after which it is mixed with coffee.

ASTRONAUTS GET ESPRESSO MACHINE

TECHNOLOGY The astronauts of the International Space Station can now look forward to enjoying a cup of hot, freshly-made espresso.

The Lavazza coffee producer and Italian engineering firm Argotec has designed the ISSpresso, which is the first coffee maker to function when a ship or habitat is in free-fall (or zero-g).

The ISSpresso weighs about 25 kg and brews creamy, aromatic coffee using capsules in the same way as some espresso machines on Earth.

The machine can also make soup, tea, coffee, and other hot drinks.

▶ 600,000

hot dogs are removed by ants in New York City annually. An army of ants keep city streets clean by consuming the remains of hot dogs, potato chips, and other food scraps that we leave behind on the streets.



3D PRINTED EYES COULD IMPROVE YOUR EYESIGHT

The human eye may be replaced by a sophisticated prosthetic.

HUMANS Although the human eye is an amazing invention, it is not infallible. Our vision can become impaired, the eyes may suffer inflammation or be blinded by light, and glaucoma can make us blind – but all these ailments can be overcome, according to an Italian design company, MHOX, which plans to launch an artificial replacement for the natural eye. As soon as 2027 consumers might be able to buy the artificial eye, according to the company.

MHOX aims to use the most innovative of technology such as 3D bio printers, which can print the artificial eyes layer by layer. According to the design, the company will develop eye

replacements and eyes that are much more sophisticated than the ones nature has to offer. MHOX imagines a new eye with an integrated filter, making visual impressions reddish, and an eye that can take photos of what it sees, sharing them via an integrated wireless network. But first, the real eyes must be surgically replaced by a socket which links eye and brain.

3 types of artificial eye

Both people with impaired vision and people who would like a more sophisticated view can benefit from the 3D printed eyes. The design company intends to make 3 different versions of the eye.

ORDINARY VISION

Artificial eye with the same performance as a well-functioning natural eye. Target group: people with impaired vision or eye injuries.

Characteristics

- Perfect iris
- Perfect retina

Iris

Artificial retina

SUPER VISION

An improved version providing super vision thanks to a sophisticated retina – a hyper retina. The improved eye can take photos of what it sees.

Extra capacity

- Super vision
- Filter

Storage unit

Wire

WiFi

HIGH-TECH VISION

Apart from the combined characteristics of the other two, this eye features a special WiFi gland allowing the owner to share photos and video.

Extra capacity

- WiFi
- Camera



One day, we may have 5 different sets of eyes to choose between.

How can water be low in oxygen?

Water is made up of two hydrogen molecules and one oxygen molecule. So, how can the water of a lake be either high or low in oxygen for life to survive?

Fish don't "breathe" the oxygen in the water molecules, but rely on gaseous oxygen like us - just dissolved into the water. When we talk about water being "fully oxygenated" we mean as much gaseous oxygen as possible is dissolved in a given volume.

Cold water can contain more dissolved oxygen than warm water. As water warms, it gives off some of

the oxygen dissolved within. If the water becomes sufficiently warm, it can end up so low in oxygen, that plants and animals die.

Currents spread the oxygen in the water. Without motion, the oxygen will not reach the bottom, and so, bacteria that can survive without oxygen thrive. They secrete sulphur compounds, and the combination of oxygen deficiency and sulphur kills oxygen-breathing life (like fish).

Whether water is high or low on oxygen depends on the amount of oxygen dissolved in it, not the oxygen that water molecules are made up of.

Fast motion disagrees with oxygen

The warmer the water, the more the water molecules move. The motion forces oxygen molecules out of the water, so warm water holds less oxygen molecules than cold water.



Fish typically need much more oxygen than crabs and worms, which can live on very little oxygen.

HOW ARE SYRINGE NEEDLES MADE?

Syringe needles are made by shaping a thin sheet of steel foil into a pipe in a rolling machine and subsequently welding it.

The pipe is heated and forced through small holes in a mould several times, until it has the required diameter.

The last passage through the smallest hole often takes place when the pipe has cooled, making the needle more sturdy and stiff. Finally, the pipe is cut at an angle, providing the needle with its pointed end.

Interior diameter of the smallest needle:

0.0826 mm

GETTY IMAGES

IN SHORT

WHY DON'T WE FALL ON A SLIPPERY SURFACE?

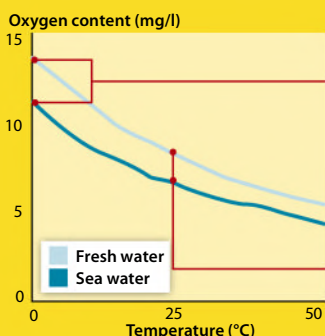
Groups of RORa neurons in the brain process large amounts of data from the skin, muscles, internal ear, and vision. Based on the data, the neurons make small corrections in the body, so we fall only on the slipperiest of surfaces.

■ Why shut one's computer down?

Occasionally shutting down a PC completely (instead of using sleep mode) lets the computer "clean up" temporary files (which saves space) and install certain updates which can improve performance and, ironically, extend battery life too!

FRESH WATER CONTAINS MORE OXYGEN

Fresh water contains fewer dissolved chemicals in the form of ions, and so it can absorb more oxygen than salt water at all temperatures.



0° At a temperature just above zero, fresh water can hold 14 mg of oxygen per litre and sea water only 11 mg/l.

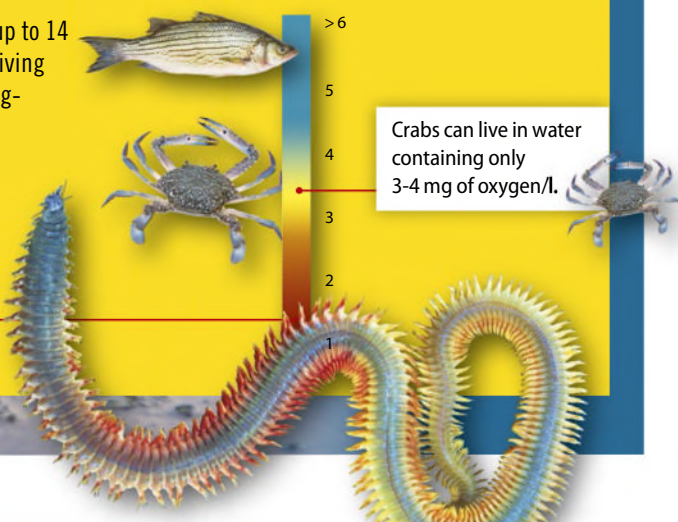
25° As water warms, the amount of oxygen it can hold drops, quickly losing up to 50% of capacity.

Fish die first

Large fish such as perch, salmon, and trout require up to 14 mg of oxygen/l. Creatures living on the sea floor, such as rag-worms, need less oxygen.

Worms require very little oxygen, and can survive on as little as 1 mg/l.

Minimum oxygen requirement (mg/l)



The death cap is lethal even in small doses.

TOP 5

THE MOST DANGEROUS TOADSTOOL?

1. Death cap (*Amanita phalloides*)

Lethal

Eating just 30 grams of this fungus is enough to kill an adult man.

2. Destroying angel (*Amanita virosa*)

Lethal

Contains a little less toxin per gramme than the death cap.

3. Funeral bell (*Galerina marginata*)

Highly toxic

Causes non-lethal kidney failure. High doses can kill, though.

4. Cortinarius orellanoides (*Cortinarius orellanoides*)

Highly toxic

Can cause severe kidney damage.

5. Brain mushroom (*Gyromitra esculenta*)

Toxic

Moderate poisoning. Not lethal.

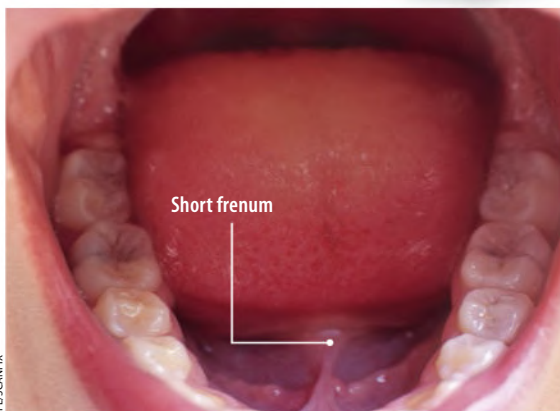
WHY DO SOME PEOPLE LISP?

Lisping is a speech impediment which often appears among young children, as they are learning how to speak. Lisping occurs when air from the vocal chord flows out in the wrong places such as between the edge of the tongue and the molars.

The causes may be physiological, such as a too short frenum (see im-

age), so the person is unable to produce correct sounds, or it may be due to incorrect tooth position. Lisping can also be deliberate. People from Catalonia lisp on purpose, as the language is pronounced with an "unvoiced S".

A child's lisp usually stops after the age of 5. If not, a speech therapist can diagnose the cause and correct it.



Short frenum

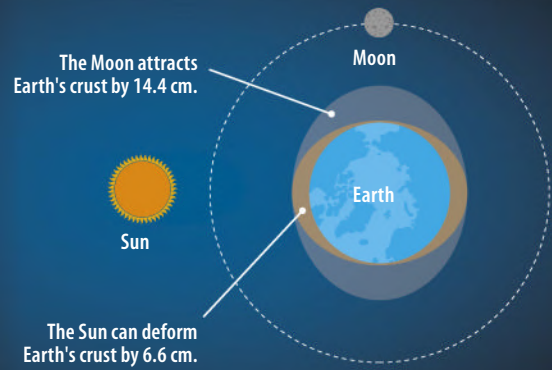
Why do cats love boxes? Species related to domestic cats often hide in caves and bushes to avoid enemies such as wolves, eagles, and foxes, and this behaviour is still deeply rooted in domestic cats.

WHAT DOES THE MOON AFFECT?

The Moon attracts all water on Earth, including that of lakes, streams, and bathtubs. But only the oceans (and a few lakes) are big enough for tides to be noticeable.

However, the Moon also attracts Earth's crust. Just like global ocean tides, two solid Earth tides exist on our planet:

one facing the Moon and one facing away from the Moon. The phenomenon is known as earth tide. The maximum height of each solid earth tide produced by the Moon is 14.4 cm. The Sun also attracts Earth's crust, but this force only produces a deformation of 6.6 cm.



Note! Illustration is not to scale.

SHUTTERSTOCK

INSIDE THE BODY

WHY DOES SPINNING MAKE YOU DIZZY?



Liquid-filled chambers in the internal ear control balance. When we move our heads, the liquid pushes sensory hairs that send nerve signals to the brain, informing it about the motion. This liquid is forced up and outward by centripetal force, and as it drains back it moves the hairs and creates a false stimulus. So, we get dizzy, because the brain thinks we are still moving.

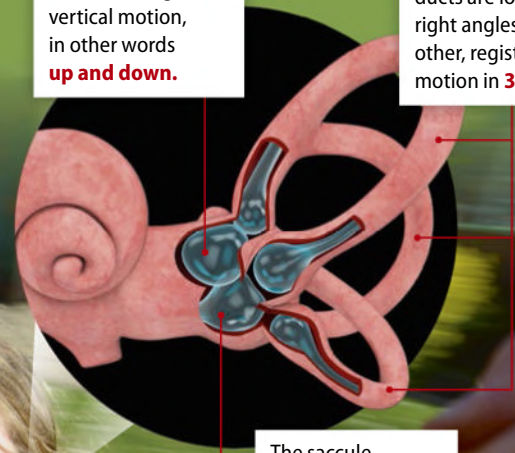
The internal ear fools the brain

Liquid in the internal ear's five liquid-filled chambers registers motion. Each chamber registers motion in a certain dimension.

The utricle registers vertical motion, in other words **up and down**.

The 3 semicircular ducts are located at right angles to each other, registering motion in **3D**.

The saccule registers horizontal motion, in other words **back and forth**.



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ASK US

THE ANSWERS
TO LIFE'S
LITTLE MYSTERIES

HOT AIR HAS GREAT LIFTING POWER

Heated air has excellent lifting power. In large airships, the balloon is filled with gases such as helium, which can lift without the use of open fire.

	Gas	Lifting power
	Hot air	1.29 kg/m ³
	Hydrogen	1.1 kg/m ³
	Helium	1.02 kg/m ³

How is a balloon controlled?

A hot air balloon is controlled by means of a gas burner, which can heat the air inside the balloon. Hot air has lower mass than the cold air outside, producing lift. A typical four-person balloon, which contains as much as 2,200 m³ of air at 100 degrees Celsius, can lift approximately 567 kg at sea level.

During a flight, the gas burner must constantly be activated and deactivated to regulate

the air temperature and the altitude. Even more importantly, the pilot must know a lot about wind movement.

A balloon will always drift with the wind, and so, the pilot must find a way to move in the right direction. Wind directions change depending on the altitude, but generally, the wind moves clockwise in the northern hemisphere and anti-clockwise in the southern hemisphere. The atmospheric pressure also influences the direction of the wind.

Warm air expands and its density is reduced — providing lift for a balloon.

What type of animal is it?

This animal with a thick, warty stalk and a “body” of white shells is known as a pelagic gooseneck barnacle.

The odd crustacean is found around the world, but is more common in warm waters, attached to driftwood, ships, marine animals, or rock. These barnacles are eaten as a delicacy in some countries.

IN SHORT

HOW MUCH SALT MAKES UP A LETHAL DOSE?

0.75–3g of salt per kilo of body weight is enough to develop salt poisoning. If you weigh 75 kg, you could get very sick eating 10 teaspoonfuls of salt all at once. The body tries to dump surplus salt via the kidneys and sweat.

SHUTTERSTOCK

MINDEN/GETTY IMAGES

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IS THERE COCOA IN WHITE CHOCOLATE?

Unlike brown chocolate, white chocolate contains neither cocoa mass nor dry cocoa, which produces the typical cocoa aroma and taste.

However, white chocolate contains cocoa in the shape of cocoa butter, which is extracted from cocoa beans. Cocoa butter is the fatty substance that makes the white chocolate melt easily on our tongues.

Cocoa beans



Cocoa butter



WHITE CHOCOLATE TYPICALLY CONTAINS:

- ~ 20 % cocoa butter (often more)
- ~ 14 % milk powder
- ~ 55 % sugar
- ~ 11 % vanilla, aromas, and additives

SHUTTERSTOCK

WILD ANIMALS

CAN A COBRA REALLY SPIT?

In Africa and Asia, there are 13 cobra species, which can release their venom in two thin squirts. Cobras use the spit as a defence, aiming for the enemy's eyes. The snake often strikes very accurately from a distance of 2-3 m. If the venom gets into the eyes, the enemy could go blind. In order to spit, the cobra uses 2 large muscles on the sides of its head to squeeze its poison glands, so the venom is sprayed out through 2 holes at the front of the fangs.



SPIT IS A WEAPON

Not only spitting cobras can spit – a number of other creatures also use spit either in defence or for hunting purposes. How far the individual animals are able to spit varies a lot.

LLAMAS spit sticky stomach contents at enemies

NORTHERN FULMARS use gastric juice

BANDED ANCHERFISH spit water at prey insects

SPITTING SPIDERS spray their prey with threads

TERMITES spit chemicals at enemies



SHUTTERSTOCK & MINDENGETTY IMAGES

How many people live to be 100+?

Today, more people live to be much more than 100 years old. In 2050, there will be 3+ million aged 100+ in the world. Right now, the number is some

—————→ **316,600**

SPECIAL EFFECTS



KOBAL COLLECTION

Is it really true that space stations could collide?

In the film *Gravity*, the Hubble telescope, the ISS, and the Chinese Tiangong space station are only a galactic stone's throw from each other. Is that really so?

Space stations, telescopes, and satellites orbit Earth at an (almost) fixed altitude. The further away a space station is from Earth, the faster it must move to keep up its orbit.

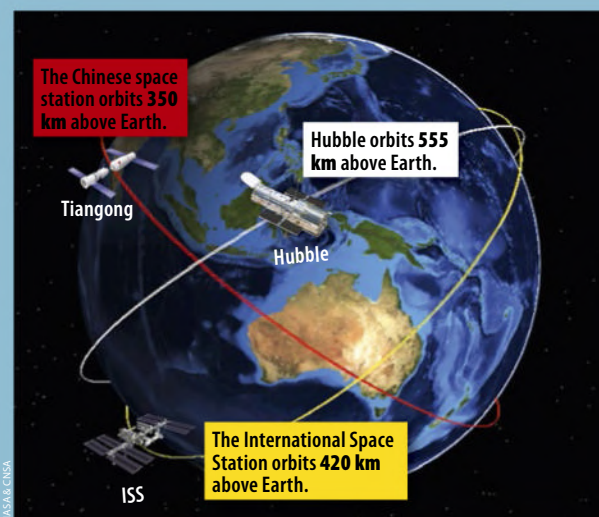
Hubble, the International Space Station, and Tiangong are often so far away from each

other that it is impossible to see from one to the others. And none of them ever come so close to each other that an astronaut would be able to take a space walk between them. The orbits and altitudes of the three objects are very different, and there is always at least 70 km between them.

Moreover, they travel at different speeds, so even if two of them were only 70 km from each other, they would quickly start to move away from each other again.

WHY SPACE STATIONS NEVER COLLIDE

The Chinese Tiangong space station's orbit cuts across Hubble's and ISS's orbits, so the three objects can never be on a line. Even when two of them are located directly above each other, there is 70-135 km between them.



LORD OF THE OUTER DARKNESS

How Pluto went from
demoted dwarf to
international superstar

After years of lobbying, years of building, the stress of the launch and nearly a decade of waiting, the team behind the New Horizons probe finally realised their dream: to see Pluto up close and personal. The result of their unlikely mission has surpassed even their expectations in almost every way.

by Anthony Fordham

When it comes to interplanetary exploration, imitation isn't just the sincerest form of flattery - it gets things done. When NASA downsized its plans for probe missions to the inner planets in the late 1970s, a group of scientists calling themselves the Mars Underground lobbied to start a new program of exploration. The result? Seven US landings on the red planet since 1997, two rovers still operational (Opportunity and Curiosity) and two orbiting spacecraft. Other nations have followed.

Seeing the success of this, another group of graduate students and planetary scientists formed in 1989, in an Italian restaurant in downtown Baltimore. This Pluto Underground was disappointed with NASA's decision to not send the Voyager probes past Pluto, instead allowing them to hurtle out of the inner Solar System after Neptune.

Ironically though, it was Voyager 2's encounter with Neptune - and its iconic photographs of the moon Triton - that boosted the Pluto Underground's case for sending a probe to what was then called the Ninth Planet. Triton appeared to be a captured twin of Pluto, based on its size, mass and apparent composition.

The Pluto Underground understood that a mission had to be built quickly and cheaply. There was a deadline too: Pluto is currently near perihelion - the part of its highly elliptical orbit that brings it close to the Sun - and so has a tenuous but scientifically fascinating atmosphere. As the dwarf planet moves further out into deep space, that atmosphere will "freeze" back onto the



► A LONG SLOW APPROACH

Four million kilometres from Pluto, New Horizons sent back this intriguing shot. The iconic "heart" is not yet visible, but will rotate around from the top left of this image as New Horizons approaches. Pluto's pole is slightly tipped toward us, in the middle of the pale grey region in the top right. Analysis of the dark geological features at the bottom will occupy scientists for years...



► NINE YEARS AGO

New Horizons launched from the Kennedy Space Centre on 17th January 2006, aboard an Atlas V rocket. Everything went smoothly.

surface by 2020. It won't return to the same spot in its orbit until 2268.

NASA's Kuiper telescope confirmed Pluto's atmosphere in 1988. It took another 18 years, various mission configurations and renamings, until New Horizons launched in 2006.

Thanks to the persistent dedication and passion of this handful of scientists, now the whole world has shared in their fascination for this almost impossibly distant world. Whether you're a staunch "Pluto is a planet!" fanatic or a more scientifically-minded "well, they've confirmed it as the biggest dwarf planet now"

progressive, we're all equally intrigued by Pluto's curiously iconographic "heart", the darkly mysterious "whale" and the unique "mountain in a moat" on the surface of too-big-to-be-a-mere-moon Charon.

Here are some of the images New Horizons has painstakingly sent back to Earth over its bandwidth-limited but very clever radio transmitter. Amazing as they are, the data won't cease to flow until the end of next year. By then, New Horizons will be irrevocably committed to its final mission. Like Pioneer and Voyager, New Horizons will now carry a tiny piece of our legacy to the stars.



▲ NIX AND HYDRA

Pluto's most famous moon is Charon (see below) but in fact the Pluto "system" is complex ballet of captured asteroids, or possibly comet nuclei. Nix (left) and Hydra are two of the large rocks, all of which orbit a "barycentre" outside of Pluto. We've yet to discover anything like this anywhere else in the Solar System.

◀ SHIPBUILDING

Like all interplanetary probes, New Horizons was constructed in a NASA "clean room" to prevent contamination by even the tiniest particles. When you're 149.6 million kilometres from Earth, the last thing you need is dust fritzing out an irreplaceable instrument.

▼ THE HEART EMERGES

Though upside-down in this image, Pluto's greatest identifying feature is the icy "heart". It's evidence of a relatively young surface - which came as a surprise to scientists working on the mission.

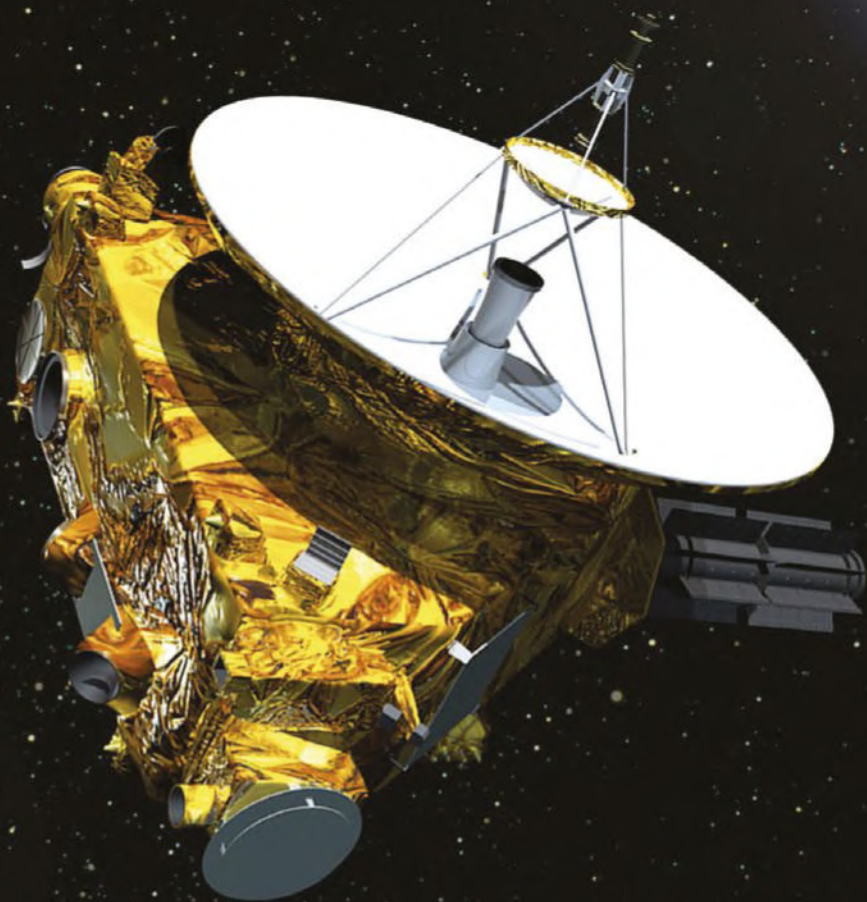


▲ MYSTERIOUS CHARON

Pluto's largest moon is thought by many scientists to be a sort of "sister planet". Only the Earth-Moon system has a similar size ratio between satellite and world. Charon's gravitational influence on Pluto is so huge, the two worldlets orbit each other. Charon is about 1200 km across - half the width of Pluto. It's also unexpectedly different, sending scientists back to their planetary formation chalkboards.

► THE MACHINE IN QUESTION

This accurate artists rendering of New Horizons (and very INACCURATE rendering of Pluto and Charon) shows exactly how small the probe is. The triangular hull is similar in size to a grand piano. The familiar dish on top communicates with Earth. The probe has a range of instruments, including LORRI. The Long Range Reconnaissance Imager captured the images you see in this article.



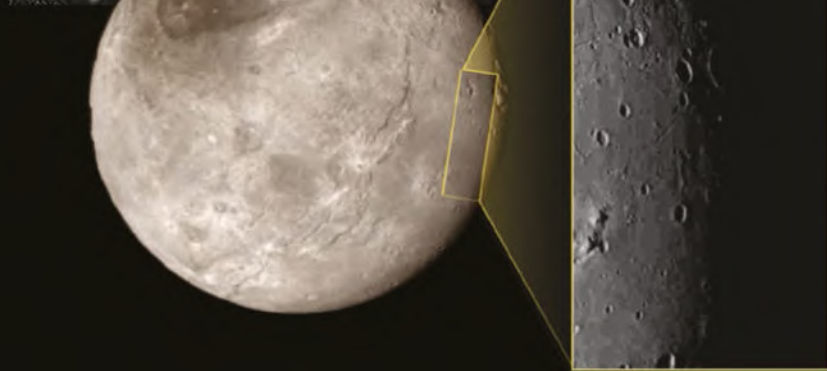
▼ THE TEAM REACTS

The scientists and engineers responsible for New Horizons cheer and clap as the last detailed image before the probe's closest approach to Pluto reaches Earth on 14th July 2015. There's much more to come - the probe will continue to transmit data from the flyby for the next 16 months.



▲ A BINARY SYSTEM

Pluto and Charon, shown to scale and coloured more-or-less as we'd see them were we there (they might appear much dimmer to our inner-system evolved eyes, though). Pluto and its moon orbit so closely they were at first mistaken for a single planet. Today, scientists discuss whether they should be classified as the first "binary planet", similar to the billions of binary star systems in our galaxy.

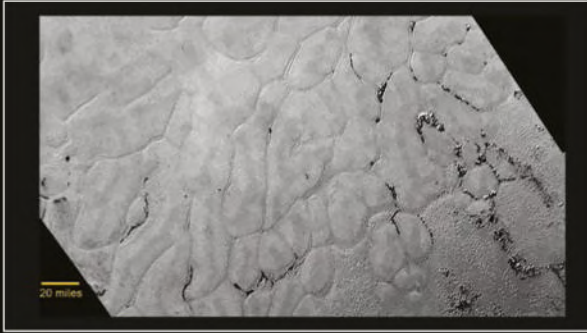


◀ CHARON'S MOUNTAIN IN A MOAT

New Horizons passed close enough to Charon (about 80,000 km) to snap this bizarre formation. It appears to be a mountain, nearly filling a depression. Dubbed the "mountain in a moat", scientists must now come up with a theory for how this unusual formation could have come about. The region marked in yellow is about 250 kilometres long.

▲ A YOUNG SURFACE?

Planetary scientists talk about "young" surfaces vs "old" surfaces. An inactive, cratered world might have a surface many billions of years old, unchanged by anything more than bolide impacts. Pluto has, at least partially, a "young" surface. Many features may still be millions of years old, but in the scale of the age of the Solar System, that's barely out of nappies. Pluto is an icy world, and scientists will use the New Horizons data to determine why the surface is changing.



▲ AN ICY WORLD

This early, compressed image of Pluto's surface shows an unexpected set of geological features. The region is covered in ice, and scientists are so far baffled as to why there are smooth areas, deep trenches, and oddly granular regions to the bottom right of the image. More data will provide vital clues.

▶ PLUTO IN TRUE COLOUR

So far from the sun, the question of "what does Pluto really look like" is hard to answer if you're not an expert in spectrography. NASA combined data from several instruments to create this image of Pluto. It's more or less what the planet would look like if you could see it from an orbiting spacecraft.



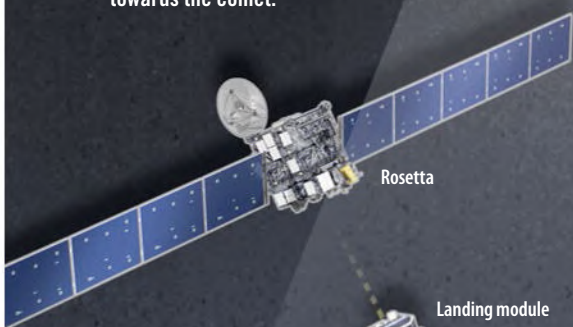
◀ MOUNTAINS, PLAINS, MAYBE GLACIERS?

Pluto's surface is more varied and fascinating than anyone predicted. Many scientists would have expected a dead and silent ice-scape, pocked with craters. But Pluto has vast plains of nearly smooth ice, strange blobs, and mountains that almost look eroded on their flanks.

80 kilometres

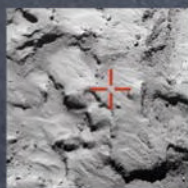


The lander seen from Rosetta on its way towards the comet.



Rosetta

Landing module



Philae remained on course and found the landing site.

The Big Bounce

The harpoons that were to anchor Philae to the comet failed, so the lander bounced along out of control.

1 TOUCHDOWN
The harpoons fail, and gravity is weak.

2 BOUNCE Philae makes an 80m-high, 600m-long leap.

Comet Hunter

snares its prey

One year ago, after travelling 6.4 billion km, the Rosetta space probe started to orbit comet 67P/Churyumov-Gerasimenko. From the orbit, a lander was sent towards the surface, but was lost in the shadows. Now, it is up to Rosetta to find out if the building blocks of life were brought to Earth by a comet.

By Henrik Bendix. Art: ESA & Mikkel Juul Jensen

Scientists have narrowed down Philae's location to a 20 x 200 m area on the "head" of 67P.



3 BOUNCE The lander touches down again and cartwheels another 600m along and 170m-high.

4 SHADOWLAND Philae settles down in a shady crater, running out of power after approximately seven hours.

For 10 years, the Rosetta space probe and its Philae lander have been on their way towards the remote comet 67P/Churyumov-Gerasimenko. Together, the two of them travelled 6.4 billion km, orbiting Earth three times and Mars once to pick up a gravity boost, set the right course and catch up with the comet, which slips through the Solar System at a speed of more than 50,000 km/h.

But now, they must part. Philae is going on a special mission. For the first time in history, the interior, solid part of a comet will be visited.

The 100 kg lander brings nine different scientific instruments, to be activated, as soon as Philae's three legs touch the comet nucleus. But first, the last 20 km from Rosetta, which remains in its orbit around the comet, must be travelled. At walking pace, Philae descends towards the surface. Where everything goes wrong.

PHILAE BOUNCES

Meanwhile, at the ESA's mission control in Darmstadt, Germany, the wait is unbearable. As the mission takes place so far away and lasts several years, not everything could be programmed before lift-off. Instead, scientists do their best to control the operation in spite of the radio signal being delayed by up to 50 minutes. So, they have no idea whether Philae makes the descent and lands safely, or if it disappears into space.

On 12 November 2014 at 5.03 PM, the tension is relieved. Via Rosetta, Philae sends a signal that it has landed. Everyone in mission control cheers. Now, the scientists are waiting for the first close-up of a comet taken from its own surface. But it is long in coming. Hours pass, and scientists receive some strange data. Apparently, Philae is still in motion.

The lander has been programmed to shoot harpoons into the comet surface ►

“

Scientists do their best to control the probe, even with the radio signal delayed by up to 50 minutes

SOME SHOOTING STARS ARE COMET CASTAWAYS

The Rosetta probe has discovered over 100,000 lumps of ice, dust, and “gravel” orbiting comet 67P. The smaller ones only measure a few cm, whereas the largest have a diameter of about 2 m. Rosetta's instruments have also detected small

particles coming off the comet nucleus's surface and being left in space. The size of sand grains, they may appear as shooting stars if they burn up in Earth's atmosphere. So, 67P confirms that tiny bits of comet can become shooting stars.



From Earth, burning comet dust is observed as shooting stars.

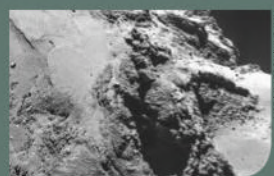
Annual meteor showers

Recurring comets, also known as periodic, orbit the Sun at fixed intervals. Meteor showers are remains of these comets, which burn up in the atmosphere.

Comet	Meteor shower	Date
109P/Swift-Tuttle	Perseids	12 August
1P/Halley	Orionids	21 October
2P/Encke	Taurids	11 November
55P/Tempel-Tuttle	Leonids	17 November
8P/Tuttle	Ursids	21 December
Thatcher	Lyrids	22 April
1P/Halley	Eta-Aquarids	6 May

COMET NUCLEUS LIGHT AS PINE

The nucleus is not a solid mass of rock. On Earth, if you carved off even a large chunk of comet 67P and threw it into the ocean, it would float. Its density is about the same as pine's – around 470 kg/m³.



NITROGEN DISCHARGED

As the comet warms up, **gases** such as water vapour, carbon dioxide, and carbon monoxide are discharged from pits and other holes in the comet. Comet 67P also contains nitrogen molecules.

TAIL GROWS STEADILY

In August, when the comet is closest to the Sun, it will spew out 100+ kg of material into space per second. This gas and dust make up **its tail**.

Comet may hold the key to life on Earth

The dust on comet 67P contains carbon compounds, some of which may be the building blocks of life.

The Rosetta probe has revitalised the theory that comets brought the building blocks of life to Earth in the form of life-giving compounds known as amino acids. The probe's VIRTIS tool measures the wavelengths of the light reflected by the comet nucleus, revealing that the surface consists of ferrous minerals and chemical

compounds made up of carbon atoms. One of Philae's instruments even sniffed out organic compounds, before the lander ran out of power. Scientists cannot yet identify the exact compounds or their complexity, but if Philae registers amino acids at some point, this would support the comet-brings-life theory.

ICE LAYER HAS MELTED

The comet's surface has not always been dry and dusty. Once, it was covered by ice, which disappeared as the Sun heated the comet nucleus. **However, there is still a thick layer of ice** beneath the dust.

Pitch-black dust makes comet 67P the darkest object of the Solar System

Comets consist of ice and dust and are normally known as "dirty snowballs". Nevertheless, astronomers are surprised that 67P/Churyumov-Gerasimenko is not only dirty, but pitch-

black anywhere on its surface. Only 6 % of the sunlight that hits the nucleus is reflected, which has turned out to be one of the darkest objects ever observed in the Solar System. The surface is very

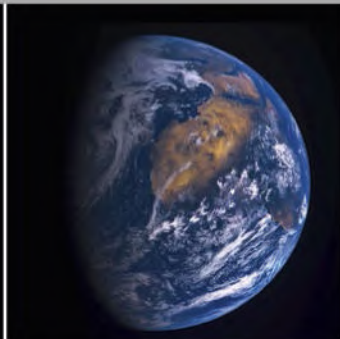
uneven and covered by a black layer of dust. In the place where Philae landed, there is 10-20 cm of dust. Before its tail forms, the comet is little more than a black shadow hanging in space.

Comet 67P: 6 %

The Moon: 12 %

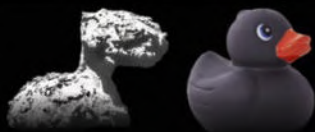
Earth: 39 %

Enceladus: 99 %



Comet 67P reflects 6% of sunlight that falls on it. Earth is bright at 39%, but Saturn's ice moon, Enceladus, reflects the most sunlight.

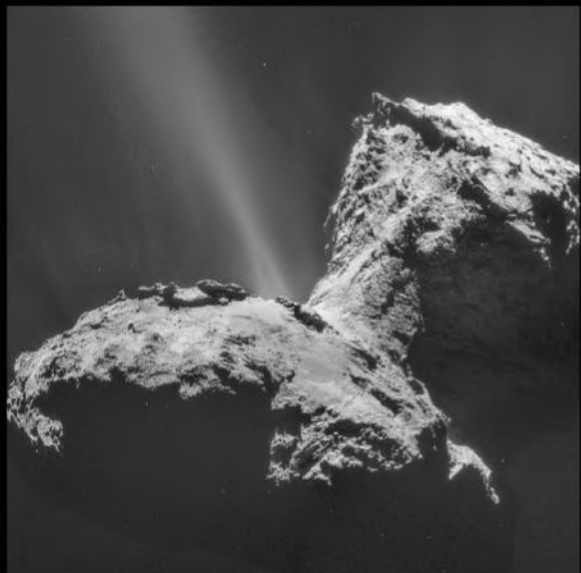
History's most photogenic comet



67P is like a rubber duck

Astronomers did not think that comet 67P was circular, but they were surprised that it looked like a rubber duckie with body and head.

Comet 67P has proved highly photogenic, and the Rosetta spacecraft continues to send amazing images back to Earth. As 67P approaches the Sun, becoming ever hotter, it produces a long tail of gas and dust.



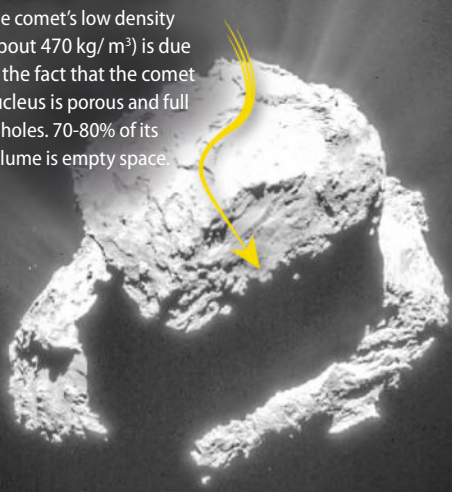
ICE IS HIDDEN

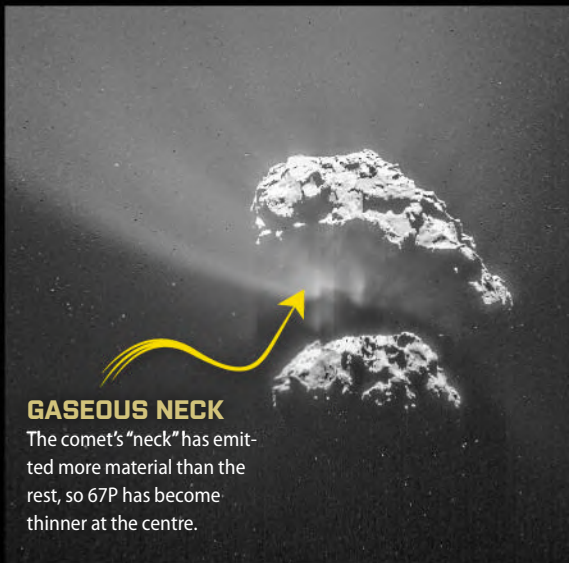
The comet's surface is covered by a layer of dark dust, concealing a thick, very hard ice layer.



FULL OF HOLES

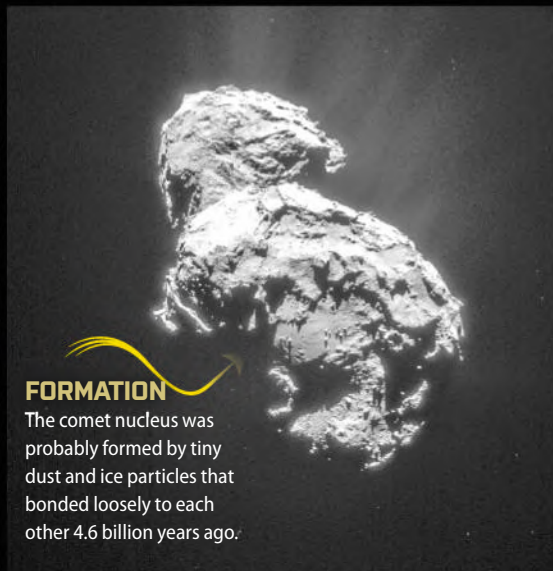
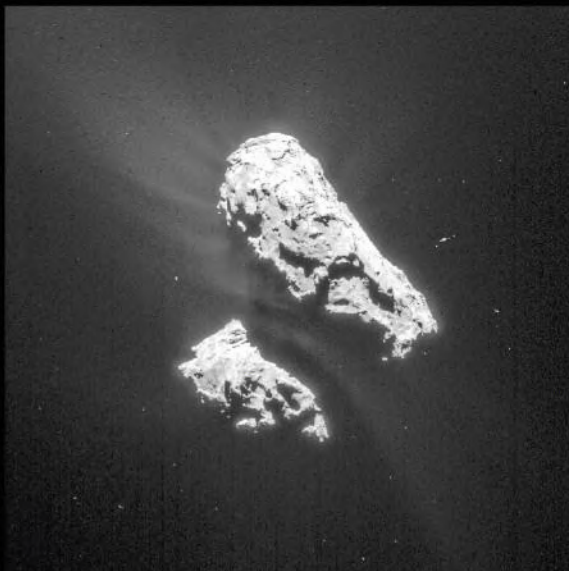
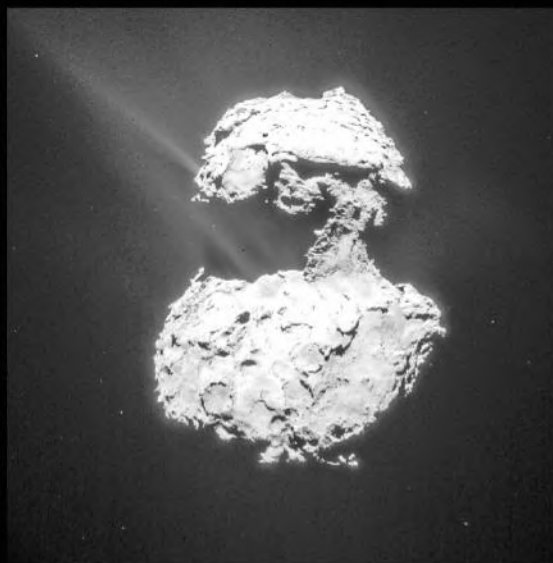
The comet's low density (about 470 kg/m^3) is due to the fact that the comet nucleus is porous and full of holes. 70-80% of its volume is empty space.





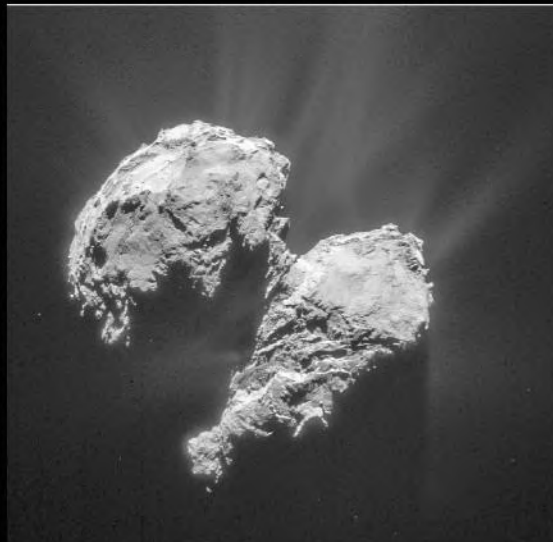
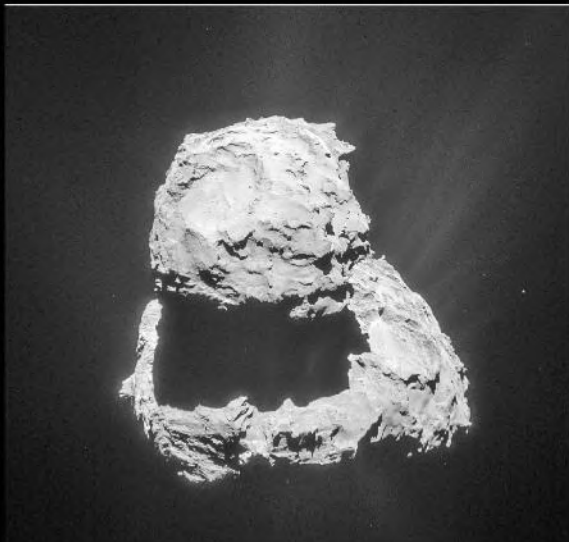
GASEOUS NECK

The comet's "neck" has emitted more material than the rest, so 67P has become thinner at the centre.



FORMATION

The comet nucleus was probably formed by tiny dust and ice particles that bonded loosely to each other 4.6 billion years ago.



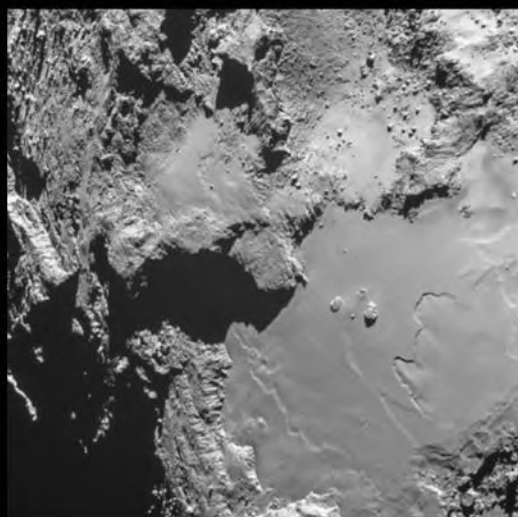
Rosetta came close

6 km is the closest scientists dared to let Rosetta come to the comet in their search for the lander.

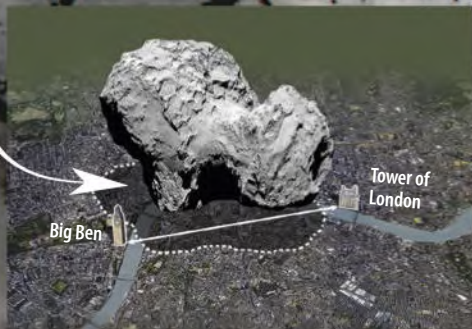
A comet nucleus spews out large amounts of dust and particles, and so, astronomers make sure that the Rosetta probe keeps a certain distance. Sometimes, Rosetta is allowed to fly close by the comet nucleus, so the instruments get a better chance of spotting particles and gases and scientists get detailed photos of the comet's surface.

The images have also been used to look for the inactive Philae lander. In the autumn of 2014, Rosetta orbited comet 67P at a distance of 10 km, and in January 2015, it was just 6 km. Now, the comet is so active that scientists no longer dare allow Rosetta close to 67P.

The comet's surface as observed from an altitude of 8.9 km.



67P IS THIS BIG



Comet 67P is 4 km long and would fit into the space taken up by most of central London.

► at the first contact. The harpoons and small rocket nozzles on top of the lander are to make sure that Philae remains at the surface of the comet, as on 67P, gravity is hundreds of thousands of times weaker than on Earth and cannot keep the lander in place. But neither the rocket nozzles, nor harpoons work, so instead of landing as planned, Philae bounces across the comet out of control.

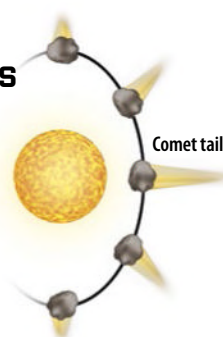
After a few hours, Philae finally settles down. Amazing images of something resembling a wall of solid rock are sent back to Earth. Humans have landed on a comet for the very first time.

PHILAE ONLY LIVED FOR SEVEN HOURS

Philae's landing was the culmination of ESA's Rosetta mission, which gained momentum one year ago, when the Rosetta space probe started to orbit comet 67P. But unfortunately, Philae has so far

THE TAIL IS ALWAYS TURNED AWAY FROM THE SUN

A comet's tail does not follow in its footsteps like smoke. Instead, it is always turned away from the Sun due to solar wind pushing the tail particles away.



contributed very little. Due to the uncontrolled touchdown, Philae ended up in a shady cleft, where its solar cells do not receive enough light to power its electronics, so when Philae's battery ran out of juice after seven hours of data collection, the lander shut down.

While Philae's role in the mission was stalled, Rosetta's instruments continued to make scientific discoveries.

Spectrometers, infrared cameras, and dust collectors revealed that the comet nucleus consists of a surprisingly hard layer of ice which will be almost impossible for

Philae to penetrate, if the lander is finally revived. And that revival is quite likely, according to ESA.

GROWING TAIL

In June, Philae once again showed signs of life, sending a 85 second message to Earth via Rosetta. According to ESA scientists, the lander is in a very good shape. They expect Philae to become still more active in the coming months, as comet 67P comes as close to the Sun as it ever will: the point called perihelion. First and foremost, it is important to send the some 8,000 data packets that Philae has already stored in its memory back to Earth.

No matter if Philae goes back to work, Rosetta will study the comet during its trip around the Sun, and scientists can observe a comet, as its characteristic tail grows and then slowly disappears.

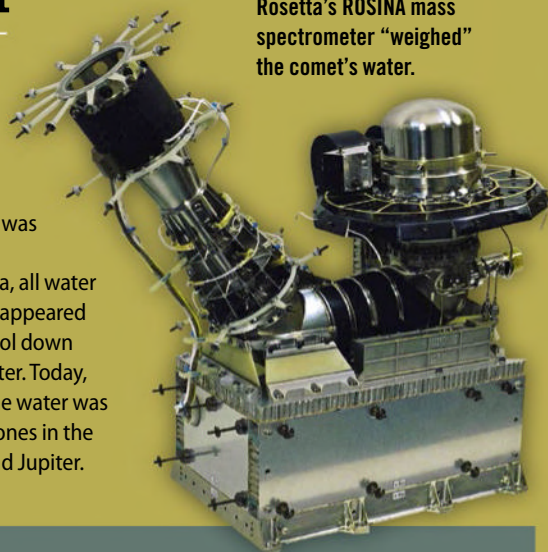
The mission ends in September 2016, when Rosetta may itself land on 67P. **sci**

COMET WATER IS HEAVY

It cannot possibly be comets like 67P that brought water to our world billions of years ago, according to surprising Rosetta measurements. One of the great mysteries of science is how the 1.4 billion km³ of water in the oceans came to Earth. Scientists used to believe that a comet shower brought the water to Earth around 4 billion years ago. But now, measurements have shown that the water of comet 67P is slightly heavier than the water on Earth. That is due to the fact that the comet's water includes three times as many "heavy hydrogen" atoms (see below) as ocean water, and so, comets such as 67P cannot have brought all of

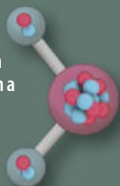
Earth's water. One explanation may be that the water was here all the way from the beginning. Scientists cannot completely rule this out, but the problem is that our planet was probably very hot when it was formed. In a red-hot sea of lava, all water must have evaporated and disappeared into space. Earth needed to cool down before it was able to retain water. Today, many scientists believe that the water was supplied by asteroids like the ones in the asteroid belt between Mars and Jupiter.

Rosetta's ROSINA mass spectrometer "weighed" the comet's water.



Heavy water molecule

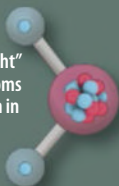
Heavy hydrogen atoms with both a proton and a neutron in the nucleus



Oxygen atoms with 8 protons and 8 neutrons in the nucleus

Ordinary water molecule

Ordinary, "light" hydrogen atoms with a proton in the nucleus



DIFFERENT TYPES OF WATER

A water molecule consists of an oxygen atom and two hydrogen atoms, but not all hydrogen atoms in water are the same. Hydrogen comes in two different, stable versions: the ordinary one with a proton in the nucleus and a heavier version with a proton and a neutron in the nucleus. In Earth's ocean water, 156 in one million hydrogen atoms are heavy. In 67P water, it is 530 in every million.

LIVING IN THE CLOUDS OF VENUS

*Wild
Vision*

Hovering above the red-hot surface and at a safe distance from towering, sulphuric acid clouds, astronauts will study Venus. NASA aims to send airships to our neighbouring planet and perhaps build an entire cloud city above its hostile surface.

By Henrik Bendix

THE BALLOON will be filled with 77,521 cubic metres of helium from large helium tanks.

THE CABIN of 21 cubic metres will be the astronauts' home during the mission

THE ROCKET will carry the astronauts back into orbit around Venus.

LENGTH: 129 metres.
DIAMETER: 34 metres.

FINS will stabilise the airship and allow astronauts to control it.

SOLAR PANELS will cover an area of 1,044 square metres.

Huge balloon to lift crew and space rocket

The airship will be longer than a soccer field and have huge lifting power. It will soar 50 km above Venus' hot surface, where thin clouds do not include too much sulphuric acid. On the other hand, the Sun shines so brightly that it will be easy to generate energy by means of large solar panels on the top side of the balloon.

NASA & MIKKEL JUUL-JENSEN

Venus is one of the most hostile planets in our Solar System. On the surface of our "sister" planet, temperatures of 460 degrees C (enough to melt lead) are what Venusians would call "a nice day". The pressure on the surface is an unbearable 93 times higher than on Earth, corresponding to diving 900 metres into the Pacific Ocean - without diving gear. The temperature and the pressure are sufficient to kill a human being in a few seconds, but that is not all. The atmosphere is also a grim place, as it

primarily consists of carbon dioxide, and the planet is surrounded by massive clouds including tiny droplets of sulphuric acid.

The US space agency NASA long ago abandoned the idea of landing humans on Venus' surface, as it is impossible to design a space suit that can resist the, well, inhuman temperatures, pressure, and atmosphere. Even the few probes the USSR sent in the 1970s were only able to function for a few minutes on Venus. The key to visiting the hostile planet is to remain at high altitude.

THE HIGHER, THE BETTER

NASA has worked out a plan of how humans can explore Venus without risk of being boiled or crushed. The head of the NASA project, engineer Chris Jones, explains that it is necessary to remain some 50 km above the planet, where astronauts can safely be placed in an airship. There, the clouds are thinner, and the pressure has been reduced to about the same level as on Earth.

At this altitude, Venus' atmosphere is a much more pleasant place to be - at ►

► least as long as you remain inside. The otherwise harmful cosmic radiation is blocked out by the outer atmosphere above the airship, and the temperature will be around 75 degrees C. Balmy!

WELL-EQUIPPED AIRSHIP

There is one good thing about visiting Venus. The planet is located only 108 million km from the Sun – Earth is 149 million km away – meaning that the Sun shines quite brightly above the clouds of Venus, making it easy to generate power for the airship's motors and other systems, and consequently, the airship will be equipped with solar panels mounted on the top side of the balloon, and during the night, batteries can power the airship and its electronic equipment.

But challenges are many. The solar panels and the rest of the airship must be protected from the sulphuric acid droplets in the clouds. Through experiments, NASA has identified teflon and the flexible plastic material polypropylene, as being highly resistant to sulphuric acid. Another challenge is the fact that the airship will arrive at Venus on a spacecraft, and it is necessary to develop a technique for inflating it, once it reaches the right altitude. Right now, NASA's main focus is Mars, as regards the first destination of a manned mission to another planet – but Venus is closer. So, scientists have prepared a five-step plan for the expedition to Venus.

The first step of the mission to Venus is a small, unmanned, robotic spacecraft. On

66

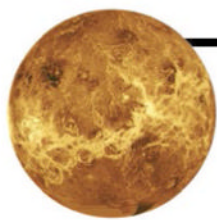
NASA's main focus is Mars, but Venus is closer. So, scientists have a five-step plan for an expedition

such a mission, the necessary technologies can be tested. First, a robotic air-ship will make measurements of Venus by means of scientific equipment that has been brought along. But the following missions will include astronauts, so NASA has also prepared a plan concerning how to get the astronauts back to Earth safely. The spacecraft, which carries the astronauts, will remain in orbit around Venus, while the astronauts are in the airship. After a mission, a rocket mounted at the bottom of the airship balloon will take them back to the spacecraft, which will subsequently return to Earth.

ROOM FOR LOTS OF PEOPLE

If NASA decides to focus on Venus, and the manned Venus airship is realised, a future including a permanent cloud city above another planet may also be possible. Huge airships – many times bigger than the first ones which NASA intends to launch – will hover permanently above Venus, lifting cabins with room for many people, so Venus can one day become a permanent destination for humanity: NASA imagines that the cloud city of Venus can be much bigger than the International Space Station, which is typically crewed by around six people at a time.

With the new project, NASA shows how a mission to Venus could be implemented, even though it will not be realised any time soon. That would require quite a few new technologies which have not yet been developed and tested by scientists. Chris Jones does not yet know when humans can be sent to Venus. But he does know that the unmanned spacecraft mission will have to wait for at least a few decades. **SCI**



A FIVE-STEP MISSION TO VENUS

NASA scientists imagine that the exploration of Venus will take place in five steps. In the long run, it may be possible to build a big space station (much bigger than the ISS) located in the atmosphere.

NASA

1 A small robotic airship measuring 31 metres is sent to Venus to **test the scientists' concept** and see, whether the airship will inflate correctly and function as planned in the atmosphere.

2 The trip to Venus and back to Earth must be proven to be safe, before a manned airship is deployed. So, **astronauts will orbit Venus for 30 days** in a spacecraft.

3 On the third mission, two **astronauts will enter the atmosphere in an airship** and stay there for 30 days. The entire mission will last 440 days, as the trip to Venus and back takes more than a year.

4 In phase 4, **astronauts will stay in the airship for a year**. The advantage is that the journey will be shorter, as it is possible to travel back and forth, when Venus is closest to Earth. The entire mission will take some 600 days.

5 Huge airships designed to be used for many years and including large cabins can function as **cloud cities**. Airships from phases 3 and 4 can bring new crews, so there will always be people "on" Venus.



WATCH: 3D printer builds houses on Mars

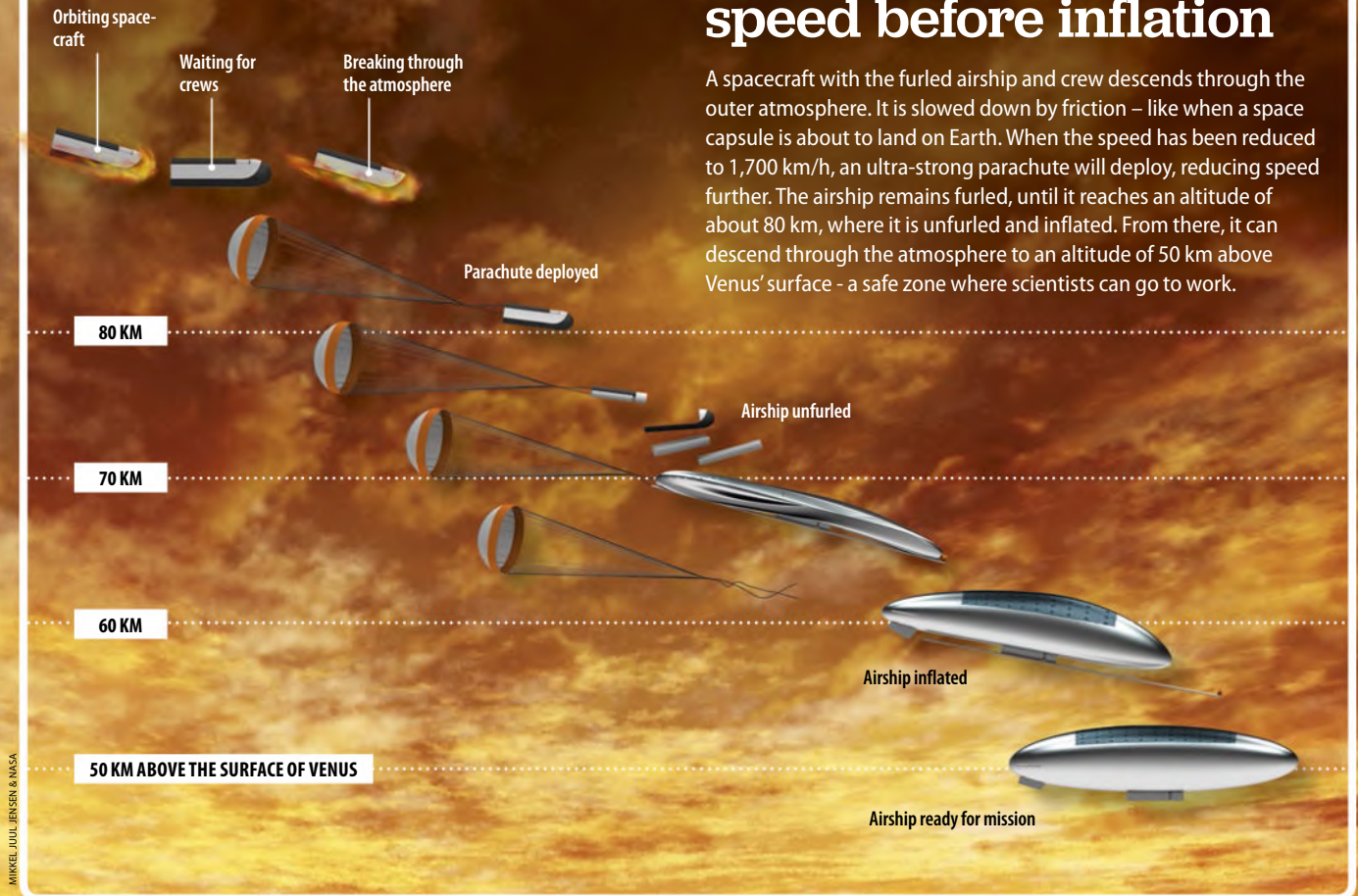


A future base on Mars can be built from 3D printers. Researchers study on the different soil that must be converted into building materials.

youtu.be/v4IbS42D8jk

Parachute to reduce speed before inflation

A spacecraft with the furled airship and crew descends through the outer atmosphere. It is slowed down by friction – like when a space capsule is about to land on Earth. When the speed has been reduced to 1,700 km/h, an ultra-strong parachute will deploy, reducing speed further. The airship remains furled, until it reaches an altitude of about 80 km, where it is unfurled and inflated. From there, it can descend through the atmosphere to an altitude of 50 km above Venus' surface – a safe zone where scientists can go to work.



VENUS' THREE GREATEST MYSTERIES

1. Was there ever liquid water on Venus?

● Venus is dry, but scientists would like to know if there was water on the planet billions of years ago. If there was, there could also have been life. Moreover, that would make it plausible that Venus and Earth got their water in the same way – in an asteroid and comet shower.

2. Are there active volcanoes on Venus today?

● Venus is crammed with volcanoes, and lava flows have renewed the planet's surface several times. If we understood the geology of Venus, we would know why the planet is so different from Earth and what it takes to form a peaceful and inhabitable planet.

3. Why did Venus become so hot?

● Venus' atmosphere almost solely consists of CO₂, making it extremely hot. A better understanding of the atmosphere can tell us if similar planets in other solar systems are also affected by a runaway greenhouse effect. If so, they will not have life.



INVENTING IMMORTALITY

In 30 years, some humans could be immortal. That is the aim of the 2045 Initiative, which intends to rid humans of our frail biological bodies and give us eternal life in avatars - a state that scientists intend to realise via four steps.

By Mikkel Meister

Try to stay alive until 2045. If you can, you may "live" forever. A number of scientists and engineers aim to develop new technologies allowing us to move our minds to avatars in the next 30 years. An avatar is an artificial body that will never age or be affected by disease. So, humans may in practice become immortal.

It sounds like something from a science fiction film, and at this point in time, the vision is also more fiction than reality. But supporters of the idea emphasise that 30 years is a long time in science. According to them, the developments of IT, medical science, robotics, and biotechnology will be so advanced by then that it will not be a question of whether immortality can be realised, but if we want it to be.

PREDICTIONS HAVE COME TRUE

The ideas of human life through avatars have been put into writing by the 2045 Initiative. The project was initiated by a Russian billionaire, Dmitry Itskov, and he is supported by leading Russian scientists specialising in robotics and brain research. The final objective of the 2045 Initiative is to spend the next 30 years developing technologies which allow us to move the human brain and mind to an avatar. In that way, humans will no longer depend on their biological "shells", so they may live forever.

Dmitry Itskov's ideas were inspired by the American inventor and self-proclaimed

futurist Ray Kurzweil.

The 67-year-old man is a director of engineering at Google and has, moreover, invented a small scanner and digital text recognition. In the 1980s, he predicted that the Internet would be for everyone, several years before it happened. And in 1990, he predicted that a computer would beat a human being in chess in 1998 - which came true in 1997, when IBM's Deep Blue computer beat World Chess Champion Garry Kasparov. The future was a year early.

In other words, Ray Kurzweil is good at hitting the bull's eye, when it comes to predictions. As of now, his most extreme prediction concerns the so-called technological singularity - the epoch- ▶

The 2045 Initiative aims to move the human mind to an avatar, ensuring eternal life.

SHUTTERSTOCK

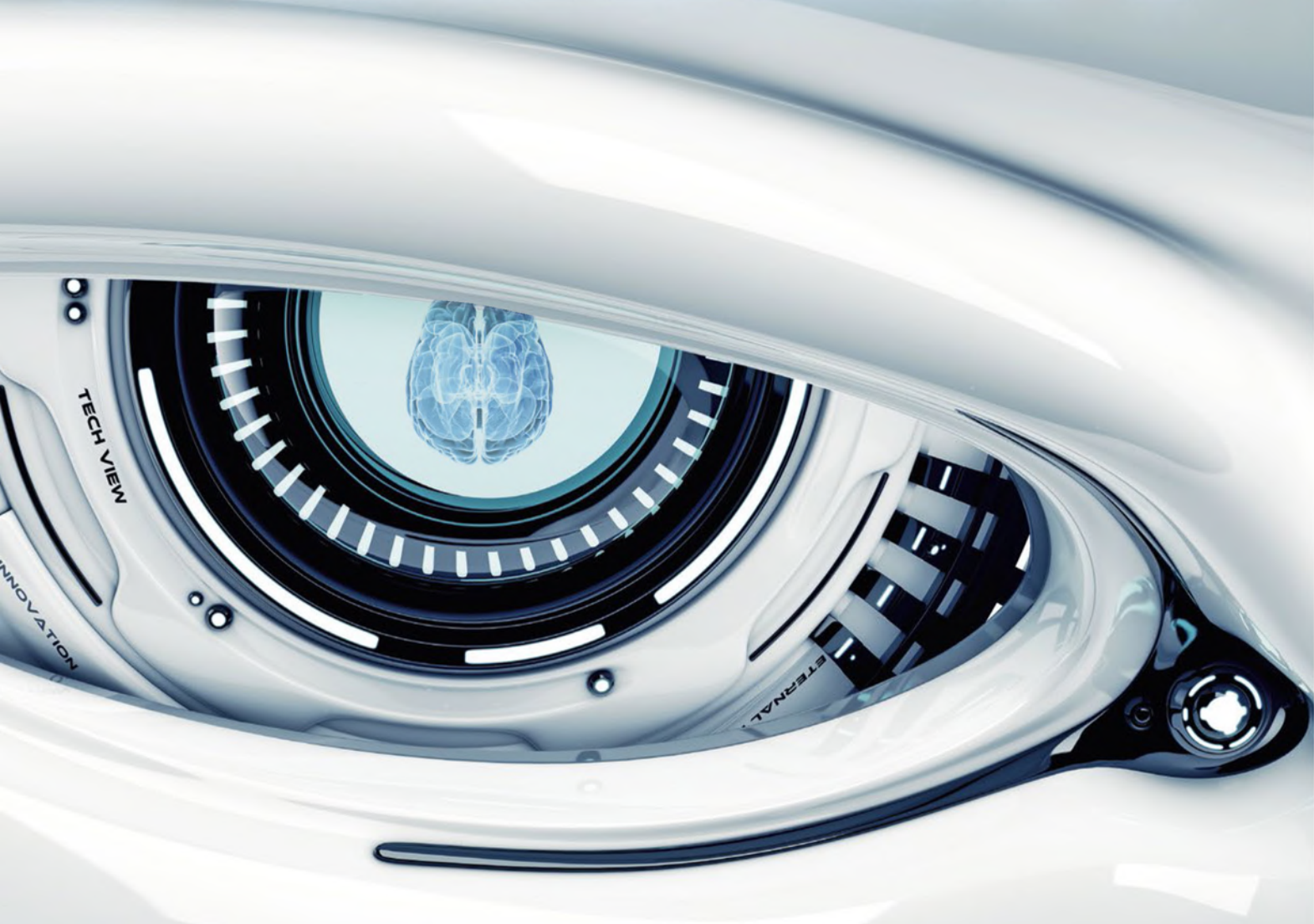
NEW FILM



THE MIND'S NEW HOME

In the new film *Selfless*, a wealthy man is dying of cancer. He is approached by a company that offers him a unique opportunity: have your mind moved into a young body, whose old mind is dead. The man chooses to say goodbye to his old, sick body and live on in the new, healthy one - but of course there is a catch.

IMMORTALITY



4 STEPS TO ETERNAL LIFE

1

Our brain remote-controls robots.

CLAUS LUNAU



2

The brain is moved to a robot.



3

A brain is scanned and uploaded.



4

Humans only exist as holograms.



► shifting point when artificial intelligence outdoes the human brain. The term has been borrowed from the world of physics. According to the theory of general relativity, a singularity is the point inside a black hole, from which not even light can escape. Once the technological singularity has been achieved, it will be possible to make a digital copy of the human brain and mind, which can take over the brain's place in the head of an avatar. So, humans will be able to say goodbye to their last bit of biodegradable

tissue and look forward to eternal, digital life. We will no longer be dependent on our bodies, and diseases which are incurable today will be irrelevant in the 2050s.

According to Ray Kurzweil, singularity will be achieved around 2045. And that is not pure guesswork, rather an extrapolation of present developments. His calculations are based on a phenomenon which he calls "The Law of Accelerating Returns": The technological development can be described as an exponentially rising curve.

So far, that has been correct in the case of computers, whose processing power has doubled every 18 months, and according to Kurzweil, the development will continue over the next 30 years.

BRAIN COMPLEXITY IS A PROBLEM

The dream of immortality through technological development is not a new one – it is known from the world of science fiction going back several decades. But ►

2015-2020

1 Our brain remote-controls robots
The first avatars are robots that function as an extension of the human body. They could be robotic limbs or small robots controlled directly by the human brain.



Robots controlled by the power of thought

Within the next five years, the people behind the 2045 Initiative expect the number of mind-controlled robots to increase considerably. They could be artificial limbs or small, independent robots, which can assist humans in connection with rescue missions.

And we already have the technology. At the opening of the 2014 Soccer World Cup in Brazil, a 29-year-old Brazilian, Juliano Pinto, kicked off the tournament, though his lower body is paralysed. The miracle maker is an exoskeleton – an external skeleton supporting the body – that Juliano Pinto was able to control

by thinking about the motion, kicking the ball across the soccer field. Electrodes in his brain captured nerve signals, sending them to a computer, that interpreted them, passing the message on to the skeleton.

In 2012, the first human managed to control a robot by the power of thought and across a long distance. Using a brain scanner, Israeli university student Tirosh Shapira was able to control a small humanoid some 2,000 km away at the Beziers Technology Institute in France by thinking about the motions of the robot. The scanner measured his brain activity, very accurately revealing the direction in which he thought about walking. The brain waves were turned into digital commands, which were sent to the small robot via the Internet.

In order for similar robotic avatars to be part of our future everyday lives, it must be very much easier to connect brain and robot – without the use of wires and scanners. The Blackrock Microsystems company and scientists from the Brown University have taken the first step with an electronic capsule placed on the skull, capturing brain activity via electrodes in the brain. The signals are sent over the air to a receiver controlling a computer mouse, robotic arm, etc.

Wireless brain control

A new capsule uses the brain's signals for wireless control of a robot.



- The capsule weighs 43 g.
- Placed on the skull, it receives a signal from electrodes implanted in the brain.
- Data is transmitted wirelessly to a computer, that converts them into motion.
- The capsule boasts a battery life of 48 hours.

BLACKROCK MICROSYSTEMS



An exoskeleton from the US Duke University, etc. allowed a paralysed man to play soccer.

CARTER DOW PHOTOGRAPHY/EKSO BIONICS

2

The brain is moved to a robot

In the second stage of the 2045 Initiative, avatars will take over the role of brain covers from the biological body - the human brain gets a new home in a robot.



Heads on the move

It must be possible to remove the brain and mind from the body of a sick or disabled person, so they can go on living in a new, artificial body with all the usual bodily functions. That is the aim of the second stage of the 2045 Initiative.

So far, scientists have not experimented with creating robotic bodies, in which the human brain is the only thing that remains from the biological body. Brain surgeons have managed to transplant entire heads from one biological body to another several times – but they were animal heads, and the owners only

survived for a few days. In a few years, the first human heads could be transplanted. In 2017, Italian brain researcher Sergio Canavero intends to try to move a human head onto a new body. The patient will be a 30-year-old Russian, Valery Spiridonov, who suffers from Werdnig-Hoffmann disease, which makes his muscles shrink, so he is forced to use a wheelchair. The surgery is not all that easy: The body's immune system may reject the new head as a foreign body, and the spinal links between body and head, including nerves and blood vessels, are

difficult to recreate. However, transplants of entire heads are still more likely than transplants, in which only the brain is transferred to a new body, as the risk of harming the frail tissue is greater, if the brain is exposed.

In 2017, a brain researcher intends to place a human head on a new body.

AGF EDITORIAL/SIPA/SCANPIX



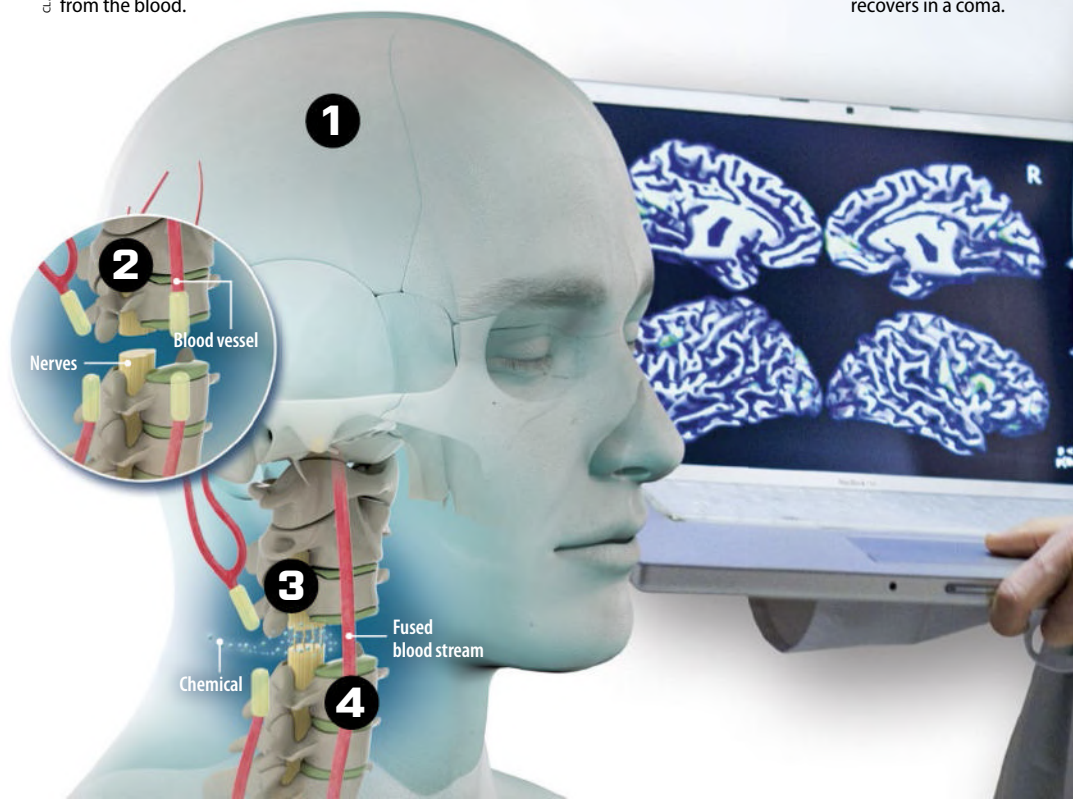
SERGIO CANAVERO

The head finds life in a new body

Sergio Canavero has worked out a careful plan of how he intends to proceed, when he transplants a human head onto another body.

1. The patient's head and the donor's body are cooled, so the tissue can survive longer without oxygen from the blood.
2. The tissue around the neck is cut open, and small plastic pipes are placed at the ends of the big blood vessels. The spinal nerves are cut.
3. In order to make the cells of the spinal cord heal again, a chemical is injected to speed up the process.
4. The ends of muscles and blood vessels are linked between the head and the new body. The patient recovers in a coma.

CLAUS LUNAU



► the artificial intelligence, etc. developments of recent years mean that the idea now seems more realistic, and several scientists are willing to discuss it.

IS THIS A FUTURE WE REALLY WANT?

But not everybody agrees with Ray Kurzweil and the team behind the 2045 Initiative. Microsoft cofounder Paul Allen, who also

funds brain research, has criticised the futurists' idea of a digital copy of the human brain and mind. According to Allen, we know very little about the brain, which seems increasingly complex, the more we learn about it. So, there is no saying that we will ever be able to understand how the brain functions. Research indicates that the mind is complex cooperation between many parts of the brain, and so, scientists may

well encounter insoluble problems in trying to solve the mystery of the brain.

And that is an important question mark considering the very aim of the 2045 Initiative. If the brain cannot be digitised, humans cannot seriously stop depending on our frail, biological bodies and develop into a new, immortal species. We will live to many times the age of our ancestors, but true immortality might have to wait. **SCI**

2025-2035

3 A digital brain version is developed
Once a complete computer model of the human brain has been made, our entire mind can be moved onto a computer. So, humans have become immortal.



The brain is imitated by computers

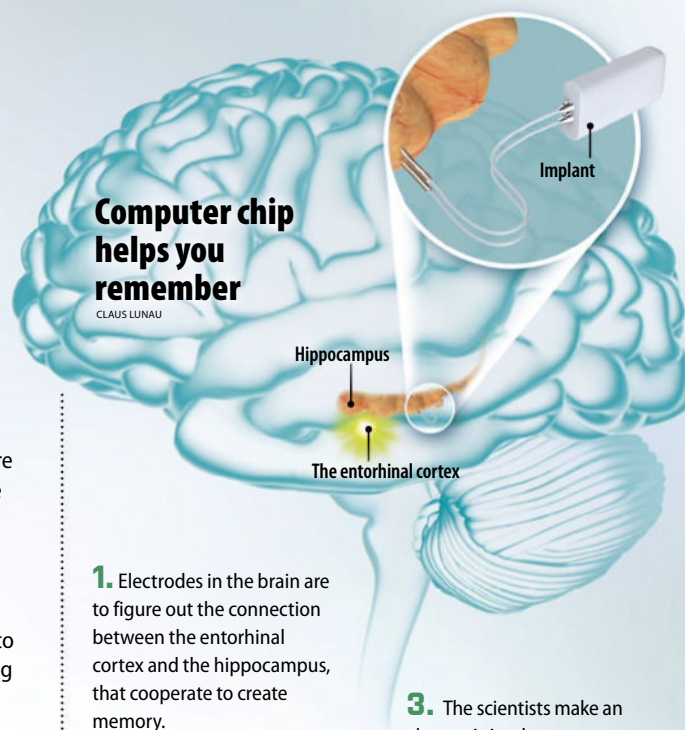
If scientists manage to make a digital copy of the human brain, the world will forever be a different place. Our mind can be moved onto a computer linked with a robotic avatar, through which we can live, and humans will be immortal.

Given the explosive development in computer calculation power, the scientists behind the 2045 Initiative believe that in 15-20 years, we will have found the brain's secrets. Today, the human mind and intelligence have not by far been worked out completely, but the mapping out is already going on. The scientists of the Human Connectome Project, a joint venture between the University of California and Harvard University, are collaborating to produce detailed 3D computer models of the brain's tangled network of neurons to understand how they are connected.

Scientists from the DeepMind company, which is owned by Google, are developing artificial intelligence, including a network of artificial brain cells programmed in computer code. Their computer programme has taught itself to play several of the classic computer games of the 1980s

Atari 2600 game console. The games are very simple to understand for humans, so the programme is nowhere near our intelligence level, but it is the first to have taught itself something without being fed data in advance.

Scientists from the University of California, Los Angeles, and the University of Pennsylvania are trying to figure out human memory, developing a brain implant that can restore the memory after brain injury, etc. They aim to map out how the brain stores and retrieves memories, developing a computer chip to be plugged into the brain, kick-starting memory.



1. Electrodes in the brain are to figure out the connection between the entorhinal cortex and the hippocampus, that cooperate to create memory.

2. The data is used to make a computer model of how the brain stores and retrieves memories.

3. The scientists make an electronic implant, including a computer chip, that can be plugged into the hippocampus, stimulating the memory to work again – recreating memories.

The brain is the most powerful computer

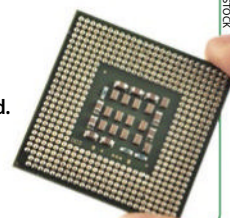
Computer power is doubled every 18 months, but nevertheless, computers still cannot match, nor beat the brain.

Two is the factor by which computer processing power grows every two years, according to the so-called Moore's law. Nevertheless, computers cannot match the human brain.

The fastest computer in the world, the Chinese Tianhe-2, can make

33,860,000,000,000,000

calculations per second. The human brain boasts around 100 billion brain cells, which are each linked with another 10,000, where they can produce 1,000 impulses per second. To match the speed of the brain, you would need a computer which can make one billion billion calculations per second – corresponding to 30 Tianhe-2s.



4

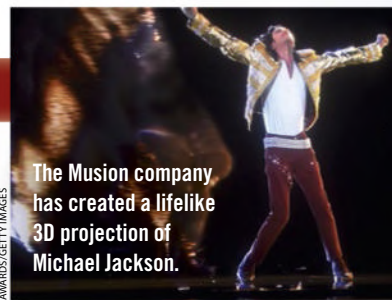
Humans only exist as holograms

In 2045, humans will say goodbye to their physical bodies, evolving into a new species. We will only exist as optical holograms, which also contain our digital minds.



KEVIN WINTER/BILLBOARD AWARDS/GETTY IMAGES

The Musion company has created a lifelike 3D projection of Michael Jackson.



Humans become images

A 3D hologram which looks just like the human body that we know today. That is the 2045 Initiative's idea of the physical appearance of humans in 30 years.

Exactly how this will be possible, the group does not know, and modern science is a long way from realizing the objective. So far, people have only been recreated as lifelike 3D projections. The DVE company has developed a

device, by which the participants of a meeting can be projected as 3D holograms. But those are not genuine, stand-alone holograms as we know them from science fiction films, in which they consist of molecules organized in the air. The images must be projected onto a screen and are only convincing viewed from the front. Scientists from

Queen's University have created a technology including a cylindrical display, allowing the hologram to be observed from all angles.

Attend meetings in the shape of a hologram

Scientists from Queen's University in Canada have developed hologram technology that includes a cylindrical display which can project a person as a 3D image. The image quality is not impressive, but the technology allows people to move all the way around the hologram.

HUMAN MEDIA LAB

1. The image of the person is displayed on a 1.8-m-tall, partly transparent acrylic and metal cylinder.

2. Cameras record 3D video all the way around the cylinder, so the person, who is not present, can see the surroundings of the hologram.

3. A 3D projector at the bottom of the cylinder projects a surround image of the person onto the inside of the cylinder using a mirror at the top of the cylinder.

4. It is possible to move around the cylinder, looking at an image of the person from any angle. So, you are under the impression that you are facing a real person.





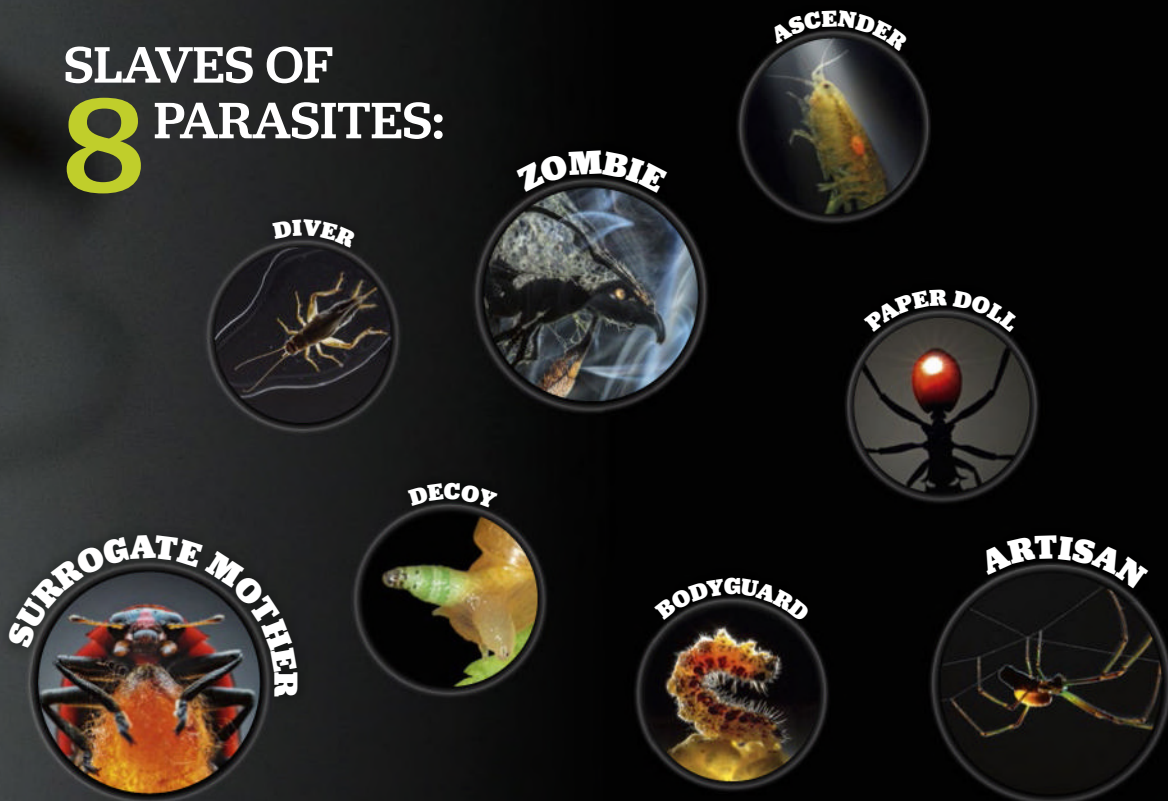
The parasitic wasp manipulates ladybirds to guard its pupated offspring.

They conquer their hosts' brains, keeping them high on chemical cocktails. They use their victims as transport, storerooms, or bodyguards in their own struggle to survive. The manipulated hosts obey orders without question, sacrificing their lives in honour of ...

DEATH'S PUPPETEERS

By Mette Iversen. Photos: Anand Varma/National Geographic Creative

SLAVES OF 8 PARASITES:



Ladybirds are the bodyguards of a parasitic wasp

After having consumed some of the interior of its host, the parasitic wasp larva pupates between the creature's legs, turning the ladybird into a passive bodyguard.

A paralysing bite from a parasitic wasp turns the ladybird into an unresisting slave. After drugging its victim, the wasp lays an egg inside the ladybird's body.

The egg hatches into a hungry larva, which satisfies its hunger by consuming the ladybird from inside. The larva chooses its menu very carefully. To safeguard its own future, the larva

must keep its host alive, so it avoids vital organs, feasting on fat instead.

When the larva has consumed enough to pupate, it eats its way out through the ladybird's belly to produce a silk pupa between the ladybird's legs and go to sleep.

If the ladybird is among the 30-40 % of hosts that survive the parasite's treatment,

it will now function as a strapped down bodyguard, using its legs to kick enemies away – because along with the egg, the wasp injected a virus into the ladybird, which allows the larva to control its host's brain and legs.

Experiments have shown that the larva stands a much better chance of surviving and becoming an adult, if it has a living bodyguard.

Ladybirds make excellent bodyguards, as they contain toxins which, along with their colour, keep predators away.

FROM FOOD TO GUARD



1. The *Dinocampus coccinellae* lays an egg inside the ladybird.



Ladybird (North American species)

2. The egg hatches, and the larva feeds on the ladybird's interior.



Larva

3. When the larva has grown big, it crawls out of the ladybird.



Pupa

4. The larva pupates, and the host 'guards' the pupa.

Cricket happily goes on a suicide mission

This type of cricket can't swim, but a horsehair worm manipulates it to jump into the closest pool of water.

Paragordius varius larvae thrive inside the fatty bodies of crickets. But the adult horsehair worm needs water to reproduce, so it manipulates its host to take a lethal swim.

The horsehair worm larva sneaks into its host's body via dead insects, which the cricket feeds on. Once inside the host, the parasite releases "drugs", which force the cricket's brain to be attracted to light. At night, the light of the Moon is reflected in lakes, streams, and ponds, and in its unresisting state, the spellbound cricket hurls itself into the water.

The water is the horsehair worm's sign to leave its host, which subsequently drowns.

The horsehair worm leaves its host's body after having forced the cricket into the water.



Scientists have found a 15-45-million-year-old cockroach fossil with a horsehair worm coming out of its body.

Eye stalks become multicoloured bait

With their tentacles infected by flatworms, gastropods crawl directly into predators' mouths.

Seen through the eyes of a bird, they look like two delicious larvae. The bird feasts on them, but is cheated. What seemed to be larvae are really infected tentacles – the eyes of a snail. The mission is accomplished for the flatworm, *Leucochloridium paradoxum*, which conquered the eyes.

Gastropods eat bird droppings, which contain flatworm eggs. When they hatch, the offspring spreads to the tentacles, that turn into brightly

coloured, larvae-like outgrowths. The offspring also manipulates the gastropod to venture into the light to attract birds.

For the rest of its life, the flatworm lives in bird guts, and to reproduce, it lays eggs, which are aimed at new gastropods in the form of bird droppings.

Flatworms find their way to tentacles, making them look like larvae.



F HECKER/IMAGESSELECT

Ants use a parasitic weapon against zombie fungus

An attack by the *Ophiocordyceps unilateralis* parasitic fungus can kill an entire ant colony. The fungus converts the ants into zombies before they die, and from the ant grave, the fungus spreads its spores. But another fungus known as a hyperparasite comes to the rescue of the ants.

1 The *Ophiocordyceps unilateralis*' spores turn a rainforest floor into a minefield. When ants come down from the canopies to find food, the spores strike. **They take over the ant's body, manipulating the host** to the underside of a leaf, where the ant's mandibles secure the small insect. Now, the fungus kills its host, growing from the ant's head and releasing new spores.

2 But the ant carries a parasitic fungus, which can save the entire colony. As the *Ophiocordyceps unilateralis* makes its way through the dead ant's head, the fungus launches a counterattack. **It attacks the *Ophiocordyceps unilateralis***, so only 6.5 % of its spores survive - it cannot spread very effectively. One infected ant has died, but the colony survives.

3 But in a twist, the hyperparasite fungus' counterattack eventually benefits the *Ophiocordyceps unilateralis* and may be **key to its survival**. When the hyperparasite fungus prevents the entire ant colony from being infected and dying, it keeps the balance, ensuring that the *Ophiocordyceps unilateralis* still has living hosts. After all, if there are no ants, there's no fungi.



The fungus grows from the ant's head.

Zombie fungus

Zombie fungus

The zombie fungus' outgrowths penetrate the ant's head in a wide variety of different and terrifying ways.

BODYGUARD



The caterpillar guards the parasitic wasp pupae.

A brainwashed caterpillar spins its own death sentence

The white cabbage butterfly caterpillar protects wasp pupae with its life.

The *Cotesia glomerata* parasitic wasp lays its eggs in the caterpillars, where they hatch. When all the parasites have feasted on caterpillar fat and grown to the size of rice grains, they eat their way out through the caterpillar's skin.

Beforehand, they have manipulated the host's brain. The "babies" spin pupae, but to get more protection, they make

the caterpillar cover them in silk. The caterpillar sits down on the pupae with its head raised, ready to chase enemies away. Exhausted by the bodyguard job, the caterpillar finally collapses and starves to death.

The parasite was introduced to North American agriculture in 1883 to combat the white cabbage butterflies that posed a threat to crops.

PAPER DOLL

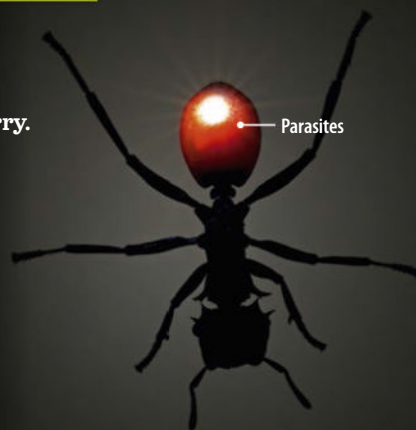
"Costume" attracts birds

Birds are experts on spreading roundworm eggs. The trick of making one's way into a bird stomach is all about crawling into an ant and making it look like a berry.

A bird dropping is a delicious meal for an ant, but the meal may turn out to be fatal. The contents of the dropping make the ant's abdomen swell into a red ball, which looks just like the juicy, red berries that grow in jungle tree canopies, where the ants live. Moreover, the abdomen points upwards. The transformation functions as bait for jungle birds, which usually do not

eat ants, but love berries. The fatal bird dropping contains the *Myrmeconema neotropicum* roundworm's offspring, which thrives in birds.

When the ant eats the offspring, the parasite lays eggs inside the ant's body. Hundreds of eggs accumulate in the abdomen, making it swell, so the parasite can get back into a bird body.



ASCENDER



Dazzled water fleas swim towards the light... and death

Water fleas thrive at the bottom of lakes, far away from the dangerous beaks of birds hunting at the surface. But a parasite changes all that.

On the muddy bottoms of lakes, the *Gammarus locusta* water flea lives a quiet, safe life far away from bird beaks. But when the *Pseudocorynosoma constrictum* parasite larva infects the

Water flea pigment makes the parasite orange, as it feeds on its host.

water flea by means of chemicals such as serotonin, the dazzled host swims towards the light at the surface, where it becomes easy prey to ducks and aquatic birds.

Again, in the stomach of a bird, the parasite thrives. After maturing, it sends its offspring back towards the muddy lake bottom via bird droppings.

1. The parasitic wasp paralyses a spider with a sting, and then lays an egg on the abdomen of its victim.



The larva lives on the back of the spider.

2. The egg hatches, turning into a larva, which bites a hole in the spider, feeding on the host's fluids.



The larva drinks its host's blood.

3. The spider is affected by venom, making it help the larva spin a pupa.

Pupa

4. The pupa hangs where the web used to be – far out of reach of savage predators.

Manipulated web.

Poisoned spider stuck in its own web

By means of a special chemical cocktail, parasitic wasp larvae take advantage of spiders, using them as hosts to produce suitable pupae.

When a spider finds an apparently snared parasitic wasp – usually a delicious meal – in its web, it may be in for quite a surprise. The meal could turn out to be a *Hymenoepimecis argyraphaga* female wasp only pretending to be caught.

Launching a surprise attack, the wasp stings the spider, paralysing it for up to 10 minutes. Then the wasp “glues” its egg to the spider, which is about to become a slave. Soon, the egg hatches, and the hungry offspring gnaws a hole in the spider, where it feeds on haemolymph, the equivalent of the spider's blood.

When the spider was stung, the wasp also injected venom into its body; venom that takes control of the spider once the larva is ready to pupate. The spider tears up its own web, producing a design suitable for attaching the pupa of a parasitic wasp larva instead. The host dies, and the larva consumes its last meal before pupating, hanging in the cobweb far away from hungry predators.

If a pregnant parasitic wasp encounters a spider that is already carrying a larva, she will immediately kill the unfamiliar offspring, attaching her own instead.

AN APOCALYPSE BURIED IN STEEL

SPECIAL REPORT

2015

36,000 tonnes of steel will seal Chernobyl away. The power plant's protective concrete layer is crumbling, so now, a huge metal coffin is under construction, to stop lethal plutonium spreading across Europe.

By: Mikkel Meister (text and photos)

1986

After the accident, a concrete sarcophagus was quickly built around the devastated reactor building. 29 years of wear and tear have made the concrete crumble, and new sealing is vital.



Two explosions occurred at Chernobyl. The second one blew off the roof.



5,000 tonnes of sand, lead, and boric acid was dropped from helicopters.



A concrete sarcophagus was built around the devastated reactor.

REUTERS/SCANPIX & SOVFOTO/UiG/IMAGESSELECT

The 110-m-tall metal structure will be positioned around the power plant to seal it.

TOP5

HISTORY'S WORST NUCLEAR DISASTERS

The International Atomic Energy Agency, IAEA, lists nuclear events on the INES scale. The Chernobyl accident is the only event so far in which people have been killed by direct exposure to radiation.

1

CHERNOBYL, INES 7 UKRAINE, 1986

Human errors cause two severe explosions. 31 people killed.

2

FUKUSHIMA, INES 7 JAPAN, 2011

Earthquake and tsunamis make three reactors melt down.

3

KYSHTYM, INES 6 RUSSIA, 1957

Radioactive waste explodes and contaminates the Techa River.

4

SELLAFIELD, INES 5 UNITED KINGDOM, 1957

Fire in a nuclear waste plant spreads radioactive contamination.

5

THREE MILE ISLAND, INES 5 USA, 1979

Human error causes a reactor to partially melt down.

On a cool, sunny morning in March, a bus has been driving for two hours on its way from the Ukrainian capital of Kiev to the exclusion zone, which, with Reactor 4 at its absolute centre, stretches 50 kilometres in all directions. You cannot visit the place without a special permission from the authorities, and at several checkpoints, armed guards have ordered the passengers to leave the bus and show their passports.

As the bus drives past the east-facing side of Reactor 4, we are instructed not to take photos of this part of the building for "safety reasons." And the instructions continue. Do not step on the soil – keep your feet on the asphalt or concrete. Do not eat, drink, or smoke outside. Do not pick anything up from the ground or enter abandoned buildings. They may collapse.

After the first dosimeter check (a device that measures radioactive contamination of hands and feet), Science Illustrated's reporter, European Commission officials, and others arrive at the construction site, where the New Safe Confinement is about to be finished. The hangar-like steel structure gleams in the sunlight, appearing to be a state-of-the-art, modern, alien object in the Chernobyl exclusion zone, where time has apparently otherwise stood still for the 29 years that have passed since the nuclear accident.

31 KILLED IN ACCIDENT

One Saturday night in April 1986, the dream of a Soviet model society powered by the energy of split uranium nuclei failed. Reactor 4 of the Chernobyl nuclear power plant exploded, and large amounts of radioactive contamination escaped into the surrounding area. The radiation killed 31 people, several thousand individuals later developed a range of cancers, and almost 350,000 had to be evacuated.

In the working-class city of Pripjat, two km from the plant, a crowd assembled on a railway bridge to watch the burning reactor building on the horizon. The next day, all of Pripjat's 49,000 citizens had been evacuated, and none of them ever returned to the ghost city. Today, bushes grow wild in the roadsides of the corroded railway bridge, but now, it is the high steel neighbour of Reactor 4 that attracts attention on the horizon.

Known as the New Safe Confinement, the metal behemoth is a billion-dollar tomb, which will encapsulate the remains of Reactor 4 and its contents of lethal, radioactive "lava masses". The huge, silver-grey structure is 110 m high, 165 m long, and weighs 36,000 tonnes. In 2017, the giant will be moved 250 m east, using an army of customised jacks. Subsequently, construction workers will carefully seal the plant, whose name is now forever



A concrete wall protects construction workers from radiation exposure.



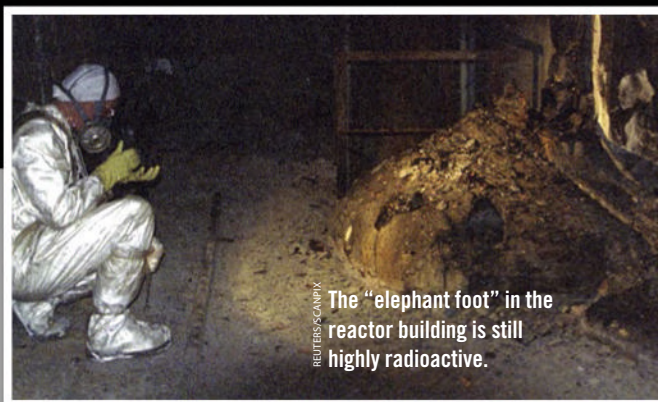
A rail system will help the 36,000 t sarcophagus reach its final position.

DEATH LOOMS IN THE SOIL OF THE EXCLUSION ZONE

Today, the Chernobyl nuclear power plant is surrounded by a 30-km-wide exclusion zone, which is still heavily contaminated.

After the accident, personnel wearing lead-reinforced clothes buried much of the debris, but the location of the objects, which are still highly radioactive, is poorly documented.

So, the exclusion zone will be off limits in the future as well. Scientists estimate that 95 % of the radioactive material is still in the area, such as fuel rods from the exploded Reactor 4.



REUTERS/SCANPIX
The “elephant foot” in the reactor building is still highly radioactive.

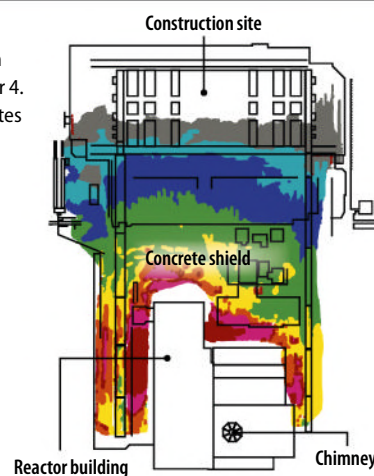
EXCLUSION ZONE



RADIOACTIVITY TODAY

Engineers constantly measure the radiation escaping from Reactor 4. The illustration indicates that the concrete wall protects the construction site.

Microsieverts/hour



associated with the worst nuclear accident in history.

A CUSTOMISED STEEL SARCOPHAGUS

Large amounts of soil and sand, including highly radioactive remains of the explosion had to be removed, before the construction site foundation, consisting of 20,000 m³ of concrete, could be laid. The concrete forms a stable base, and moreover, it protects workers against radiation from the contaminated soil.

The New Safe Confinement is also referred to as a sarcophagus, like those of Egyptian tombs, as it will be used to bury and seal Chernobyl – at a much larger scale than in Egypt: The steel sarcophagus is 17 m taller than the Statue of Liberty, it is longer than two jumbo jets, and weighs more than three times as much as the Eiffel Tower in Paris. The external steel casing of the structure stretches 86,000 m², the same footprint as about 12 soccer fields.

Sixteen transverse steel beams support the two layers of steel plate that make up the protective membrane of the New Safe

Confinement. The steel beams rest their “feet” on a customised rail system of concrete and steel that will help keep the structure on track, when it is pushed into position around Reactor 4 in 2017.

The New Safe Confinement is a unique engineering project, including several customised solutions.

The arched structure consists of a steel pipe framework including some 685,000 bespoke bolts with integrated safety devices, so they cannot be fastened too tightly, which could weaken the structure.

The New Safe Confinement is designed to resist much more violent weather than today’s cool breeze. Neither a category 3 tornado (wind speeds of 250–330 km/h) or a Richter 6.0 earthquake could make this structure tremble. It’s thanks to the builder being assisted by a company specialising in submarine hulls, whose know-how concerning the impact on

the hull during missile launches has been key to the design of the New Safe Confinement’s protective membrane.

The job of lifting the individual spans of the two halves of the arch to a height of 110 m and subsequently pushing the entire structure into position has also required special engineering expertise, and Novarka, the builder, is assisted by a Dutch company specialising in lifting heavy objects such as

the salvaging of the Russian nuclear submarine Kursk.

RADIOACTIVE “ELEPHANT FOOT”

Construction workers are lifted to the end walls by cranes and

rappel down the curved outside of the structure to mount steel plate, tighten bolts, and seal cracks. A total of some 1,200 people from 27 countries work shifts. After about two hours of work, they have been exposed to an effective radiation of 0.014 microsieverts, corresponding to an X-ray at ►

“Do not step on the soil – keep your feet on the asphalt or concrete. Do not eat, drink, or smoke outside. Do not pick anything up from the ground.”

Instructions to Chernobyl visitors

► your dentist. So, a worker can cover more than 100 24-hour shifts, before the annual limit of 20 mSv has been reached.

But though the radiation affecting the construction site and major parts of the exclusion zone has been reduced to low levels, there is a reason why the New Safe Confinement is built 250 metres from the devastated reactor building.

After the accident in 1986, 5,000 tonnes of sand, lead, and boric acid was dropped from helicopters to stop the fire in the reactor and curb the radiation. Together with nuclear fuel, control rods, radioactive isotopes, and melted concrete, the mixture produced tonnes of radioactive and hardened areas inside the reactor known as lava masses. One of them has been nicknamed the “elephant foot” due to its characteristic shape. Though the gamma radiation of the elephant foot has decreased over the years due to radioactive decay, the gamma radiation from isotopes such as caesium-137 and europium-152 still means that it is lethal for humans to be close for more than sixty minutes.

The greatest potential health hazard is constituted by the elephant foot’s plutonium content. If plutonium particles become airborne and are inhaled by people, they can do irreparable harm. Just 10 mg of plutonium-239 can kill a human in a few weeks. One of the most important tasks of the New Safe Confinement is to prevent radioactive dust from escaping the building, requiring special membranes and a unique ventilation system.

When the New Safe Confinement has been pushed into position around the reactor building, and the last seal is mounted, the men will only be allowed to work 30-60 minutes a day, as the radiation will have increased markedly at this point.

EXPENSIVE DELAYS

In 2013, large amounts of snow made the roof of the Reactor 4 turbine hall collapse, indicating that the “bandaided” reactor building desperately needs a steel structure to protect it against the continuing effects of the elements.

According to plan, the New Safe Confinement should have been finished in 2015 at a cost of approximately \$2.2 billion plus the cost of the concrete wall protecting the construction site workers against radiation and the construction of ►

AN ARMY OF JACKS TO PUSH 36,000T INTO POSITION

In 2017, the New Safe Confinement steel sarcophagus will be moved the last 250 metres from the construction site to the reactor. World class engineering expertise is required to lift the giant, push it to cover Reactor 4, and seal the plant.

MIKKEL JUUL JENSEN

1. Membrane encapsulates radioactive dust

The sarcophagus is designed to include an interior and exterior layer, constituting an up to 12-m-wide membrane. The exterior layer is designed to resist rain, large amounts of snow, and high winds for 100 years.

The exterior membrane layer consists of 2 layers of corrugated steel. The steel embeds 3 vapour barriers, which keep out moisture.

The interior membrane layer consists of stainless corrugated steel covered by a 0.5-mm-thick layer of non-magnetic steel, which keeps radioactive dust off the sarcophagus subsurface.

A ventilation system makes sure that the pressure in the membrane cavity is higher than the atmospheric pressure, keeping moisture out and radioactive dust inside.

3 dehumidifiers keep the moisture level of the cavity low, so condensation will not damage the membrane and the steel structure.

2. Jacks are employed

When the metal structure has been finished, 116 customised jacks – known as “slide shoes” – are placed at the bottom of the steel beams.

4. Slide shoes get to work

Via a rail system, the slide shoes slowly move towards Chernobyl. They are remote-controlled and synchronised to avoid irregular impacts on the sarcophagus. The moving takes two days.

3. The sarcophagus is lifted

Each jack can lift 660-826 tonnes, push 125 tonnes, and pull 90 tonnes. The New Safe Confinement will slowly be lifted off the base.

5. Chernobyl is sealed

The sarcophagus is lowered into position above Reactor 4 and sealed. A separate building is erected along the western end of the New Safe Confinement to monitor air humidity, radiation level, and seismic activity.

NEW SAFE CONFINEMENT BY THE NUMBERS:

685,000

bolts hold the 16 steel beams together.

20,000

m³ of concrete makes up the construction site base.

1,200

employees from 27 different countries work in shifts.

36,000

t is what the sarcophagus weighs – 3 times the Eiffel Tower.

6.0

Richter is what the New Safe Confinement is designed to resist. Moreover, the structure can withstand a class 3 tornado and temperatures ranging between -43 and +45 degrees C.

processing plants, in which the radioactive material will be deposited.

However, there have been delays, and an extra bill of \$1 billion must be covered within 10 years. The final cost of the lengthy project will consequently be over \$3 billion.

6,000 DEVELOPED CANCER

After a short ride from the sarcophagus construction site, the bus crosses the corroded railway bridge and drives into Pripyat, where the trees along the blocks of flats of the city cast long shadows in the late afternoon sunshine. The windows are broken, and paint peels off in the abandoned workers flats. The Soviet stars at the top of the block are still red, but that is due to corrosion, not paint, and in the amusement park, the Ferris wheel and the bumper cars stopped long ago, among withered leaves and bushes.

With its post-apocalyptic appearance, Pripyat is scary evidence of how wrong things went 29 years ago. Today, the radiation level is so low that the original

inhabitants could in move back - at least in principle - if their homes had not been in such a bad state. In the city of Chernobyl, further away from the plant, and in a series of villages in the area, a few hundred people have chosen to move back. They have lived in the area since the late 1980s.

Following the accident, there has been lots of myth-making, and claims of one million casualties have been repeated over and over again. According to the UN and the WHO, the total death toll as a direct consequence of the explosion and the radiation is 31 people. Moreover, the

“The Soviet stars at the top of the block are still red, but that is due to corrosion, not paint, and in the amusement park, the Ferris wheel and the bumper cars stopped long ago.”

authorities have registered some 6,000 cases of thyroid gland cancer in children and young people, of which many were probably due to food and drinking water being

contaminated by iodine-131 shortly after the accident. Last, but not least, you can try to imagine the psychological consequences affecting the 346,000 people, who were forced to move away from the contaminated areas of Ukraine, Belarus, and Russia.

Though the radiation has dropped over the years, and the New Safe Confinement will soon encapsulate Reactor 4, you should not expect anybody to move into the flats in Pripyat, nor see any happy children in the amusement park over the next decades. The exclusion zone is turned into a dump site, where radioactive material is handled and kept at a safe distance from people outside the zone. Over the next decades, the lava masses of Reactor 4 are to be processed and deposited in a customised plant inside the zone. The same is true for the used nuclear fuel from Reactors 1, 2 and 3, which were in operation until 2000.

RADIATION WARNING

Before we leave the Chernobyl plant, Pripyat, and the rest of the exclusion zone, it is time for a new dosimeter check.

A green light indicates that everything is okay, and the visitors pass through a metal gate one by one. I am the last one waiting in line, but I cannot leave, as the light is now red. Nevertheless, an Ukrainian employee opens the gate, politely ensuring me that there is nothing to worry about. Unnerving!

Hopefully, Ukraine will have nothing more to worry about either in 2017, when the 36,000 tonne “lid” is finally placed on the structure that turned a wooded area into a nuclear no man’s land 29 years ago. 

CHERNOBYL WILL BE RADIOACTIVE FOR THOUSANDS OF YEARS

Over time, all radioactive isotopes decay into stable elements. The half-life period is a key factor, indicating how radioactive a substance is. Counter-intuitively, a shorter half-life usually means the substance is more dangerous, as it emits lots of radiation quickly. Uranium sounds scary, but it has such low radioactivity, it is often used as radiation SHIELDING, as it is even denser than lead.

Like the rest of Pripyat, its amusement park has been abandoned for 29 years.

HALF-LIFE PERIODS OF CHERNOBYL'S RADIOACTIVE ISOTOPES:

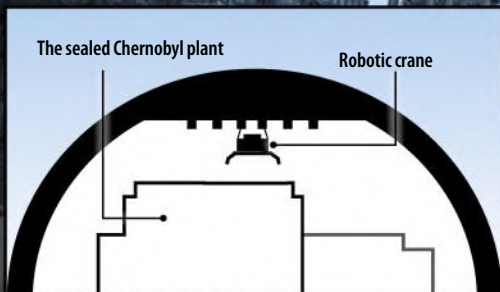
Iodine-131:	8 days
Caesium-137:	About 30 years
Plutonium-239:	24,000 years
Uranium-238:	4,500,000,000 years



ROBOTIC CRANES TO DISASSEMBLE THE REACTOR

Reactor 4 will not be left alone once it has been sealed inside the sarcophagus. According to plan, the old reactor will be completely dismantled. Robotic cranes will cut up the radioactive lava masses in the reactor and take them to a new storage deposit via a pipe system.

A rail system has been mounted in the ceiling of the steel sarcophagus, from where robots will dismantle the reactor.



The side of the sarcophagus has been adjusted to the shape of the Chernobyl plant.



Radioactive waste will be deposited in a new plant.

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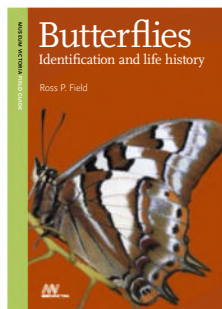
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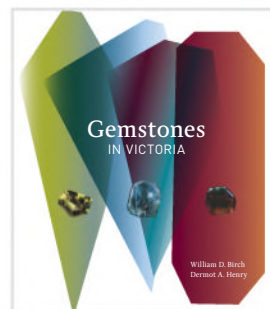
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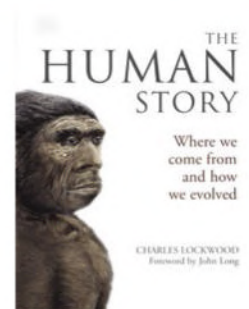
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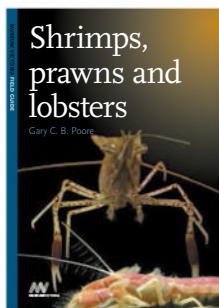
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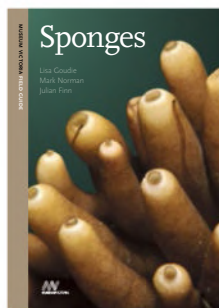
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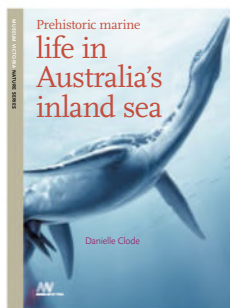
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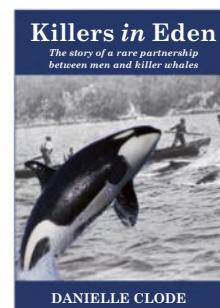
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MA/38

Fix the Planet

The oceans are a tepid, acidic soup. Genetically modified plants out-compete their natural cousins, and air pollution blackens our lungs. Humans have already massively damaged four of **Earth's nine vital systems**. Luckily, scientists are ready to carry out technological first aid: New CO₂-absorbing materials come to the rescue of the oceans, while GM plants will be pre-programmed to die.

By Niels Hansen & Anne Lykke

Danger indicator

According to scientists, Earth has 9 vital "boundaries". Our danger indicator shows how close they are to collapse, and the accompanying text suggests technological solutions.

NO DANGER:
We have not yet severely damaged the system, which can easily return to its natural state.

CAUSE FOR CONCERN:
The system is so badly affected that irrevocable changes are imminent. Technological help is necessary.

VERY BAD: The system has been destroyed, and the massive changes pose a threat to all biology. Immediate technological first aid is necessary.

UNKNOWN: Scientists still do not know enough to estimate where the boundary is, but they worry that it has already been crossed.





9 Challenges must be solved right now:

- 1. A warming Earth**
- 2. Toxic air**
- 3. Polluting agriculture**
- 4. Deforestation**
- 5. Ozone layer depletion**
- 6. Ocean Acidification**
- 7. A mass extinction**
- 8. Loss of fresh water**
- 9. Plastic and GMO clogging the ecosystem**

1

A Warming Earth

The atmospheric level of carbon dioxide, CO₂, has risen by about 125 parts per million (ppm) since the industrial revolution. If it increases by another 50 ppm, we will end up

in the red area, with heat posing a threat to animals and plants. CO₂ is a greenhouse gas holding on to solar heat, so the atmospheric temperature will increase: global warming.



Sulphur and Water can cool Earth

Global warming can be halted with big geoengineering projects, but these could have unexpected and extremely unpleasant side effects.

The sun is blazing down, and our altered atmosphere traps heat like a greenhouse, raising temps subtly but significantly. Consequently, scientists are trying to direct sunlight back into space. One method consists of producing artificial clouds of "nebulised" ocean water or sulphuric acid. The particles reflect the light, and sulphuric acid

provides the same cooling effect as a volcanic eruption. And it actually works: When the Tambora volcano erupted in 1815, global temperatures fell by 0.7 °C. Other methods focus on binding ocean greenhouse gases, so they no longer exist in the atmosphere. The binding can be done by pouring nutrients into the ocean, boosting algae growth. The ocean is low in iron, so once it is added, it stimulates algal growth. In the autumn of 2012, American businessman Russ George caused an international stir, when he tested this method, pouring 100 tonnes of iron sulphate into the ocean off Canada without asking the authorities. After the scandal died down, satellite images revealed that the iron had indeed caused considerable algal growth.

SOLUTION 1

Planes spray "cooling" sulphur 20 km above Earth

Sulphur in the stratosphere will reflect sunlight, cooling Earth.

SHUTTERSTOCK

SOLUTION 2

Barges spray ocean water, producing artificial clouds

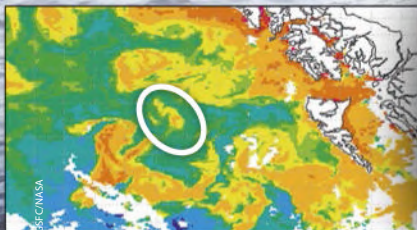


Vapourized water is sprayed into the atmosphere, producing clouds that reflect sunlight.

FLETTNER/UNL OF EDINBURGH

Sharp algal growth

After the illegal iron sulphate "spill", satellite images revealed algal growth off Western Canada.



Few algae Many algae

SOLUTION 3

Iron sulphate binds greenhouse gases in the ocean

Iron sulphate makes algae grow. When algae grow, they consume CO₂ from the air. But there's uncertainty about how the growth affects other ecosystems.

THOR SWIFT / THE NEW YORK TIMES/SCANPIX

2

Toxic Air

Annually, 7.2 million people die from breathing particulates - air pollution. But climate is hit too: the high pollution levels of South East Asia mean less monsoonal rain.



Structures Consume Smog

The brown layer of suffocating smog in which many Asian cities are covered can be combated by the cities' own structures. A German company has developed a smoke-consuming façade with a large surface area and painted with a titanium oxide-based nanomaterial, which is energised by ultraviolet radiation from the Sun. The façade functions as a catalyst, breaking down smog into harmless substances such as oxygen, carbon dioxide, and nitrogen. The surface is neither overloaded nor dirty, and it can work almost forever.

Smog is the name for a soup of problematic chemicals such as nitrogen oxides, which cause respiratory problems and may be lethal.

The Manuel Gea González Hospital in Mexico City is one of the first structures with a smog-consuming façade.

ELEGANT EMBELLISHMENTS LTD.

To the north, glaciers were pushing forwards. To the south, in the tropics of South America and Africa, average temperature variations of 5 °C made precipitation vary greatly. During one decade, several metres of rain fell, whereas a few years later, there was no rain at all. People desperately tried to survive in this unpredictable climate.

That was the situation during the most recent ice age. But 12,000 years ago, the climate stabilised. Major sections the ice melted, temperatures smoothed out, and precipitation set predictable patterns. People started to cultivate the land, and the great civilisations developed. Though humans have existed for more than 100,000 years, it

was not until after the most recent ice age - in the period known as the Holocene - that civilisations stood a fair chance.

"It would be very stupid to do something to change the conditions that existed on Earth during this period," says Professor Katherine Richardson from the University of Copenhagen. But according to new research, four of Earth's nine vital systems are suffering and changing at an unprecedented rate. At this speed, the four systems will collapse in the next 100 years - perhaps in a few decades. Earth will become a hostile place, and many people will probably starve to death. The survivors must learn to get by without pure drinking water, eating animals, or the possibility of cultivating the land.

PUSHING BEYOND 4 OF 9 BOUNDARIES

Richardson, who is a biologist specialising in sustainability, and 17 colleagues have discovered that several of Earth's

ecosystems are collapsing. Taking a look at Earth's resources, the scientists defined nine systems that must be balanced in order for Earth to function in the way we are used to. It looks as if the CO₂ content of the atmosphere will make temperatures rise for many years. Temperature increases may cause severe storms, more torrential rain, and more regions with extreme drought. Moreover, calculations indicate that animals are going extinct at a rate that resembles the major mass extinctions of the past. Published in the reputable Science journal, the scientific results describe the extent of the changes that we can afford, before we enter into a new era of geological, chemical, and biological Armageddon.

A WORLD FOR EXPERIMENTS, PLEASE

Earth's nine vital systems - such as the climate, the nutrient cycle, and ocean acidity - can all collapse, if subjected to major ►

3

Polluting Agriculture

Brightly green, toxic algae and millions of dead fish are the results of too many nutrients in streams and oceans. Phosphorus and nitrogen

from agriculture are the culprits. Emissions must stop to avoid disastrous consequences. The nutrients should somehow be reused.



Megatonnes of nitrogen/year



Megatonnes of phosphorus/year

Cleaner, greener food

Fish and vegetables can be grown on roofs in sealed, non-polluting systems. The method is gaining support in Earth's most congested regions.

Let fish into a system with germinating plants and voila: Fish faeces is converted into food. Known as aquaponics, the method combines fish farming and agriculture close to the consumer. Expensive and polluting transportation is not needed, and moreover, the farmer does not have to use fertilisers – the plants get everything they need from the fish.

The system functions by fish or crustaceans such as lobsters being kept in a basin. Bacteria break down the faeces into nutrients, providing nutrition for soil-free plants. In Gaza City,

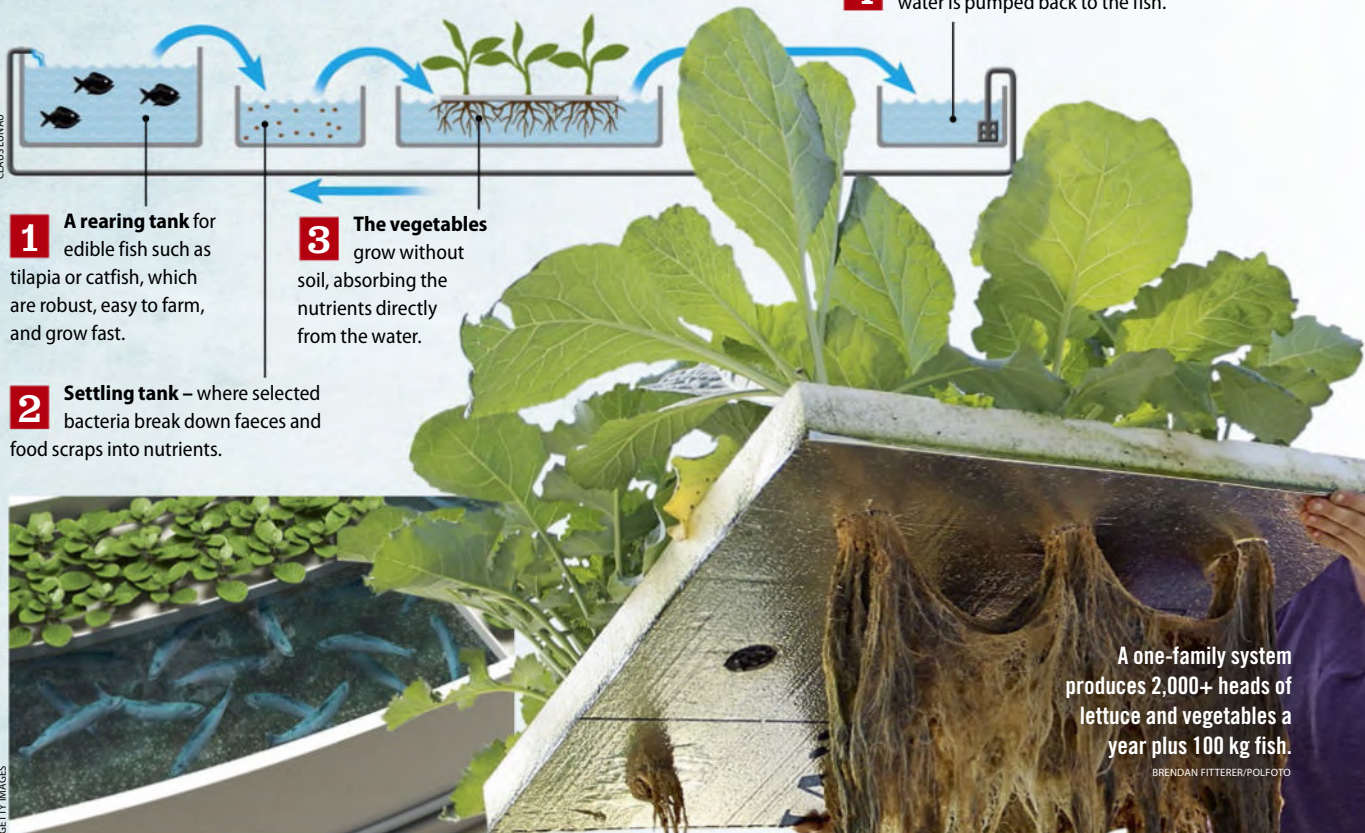
aquaponics has become popular in recent years, and the city's flat roofs function as a supplement to the limited farming carried out in the Gaza Strip – one of the world's most densely populated regions.

In the rest of the world, aquaponics is mostly a hobby. A family size system costs \$5,000 and produces 100 kg of fish and 2,000 vegetables a year, while consuming very little power. Economist Peter Drucker considers aquaponics one of the central technologies in the struggle against nutrient pollution.



In the Gaza Strip, people grow fish and vegetables on the roofs in home-made aquaponics systems to get enough food.

Fish faeces makes salad delicious



1 A rearing tank for edible fish such as tilapia or catfish, which are robust, easy to farm, and grow fast.

2 Settling tank – where selected bacteria break down faeces and food scraps into nutrients.

3 The vegetables grow without soil, absorbing the nutrients directly from the water.

4 A sump tank, from where purified water is pumped back to the fish.

The plants grow without soil by placing their roots in water, absorbing nutrients directly.

A one-family system produces 2,000+ heads of lettuce and vegetables a year plus 100 kg fish.

BRENDAN FITTERER/POLFO

► change. But scientists cannot do experiments involving Earth as a whole. So, the challenge consists in finding out when the boundary has been reached without performing global experiments.

Consequently, the scientists began looking for boundaries, where the system suddenly and often without warning stagnates or collapses. Using sophisticated computer models and huge amounts of data, the scientists calculated, when the systems will collapse. For instance, the fresh water boundary was found by entering all the information concerning water quality from all over the world, into the model.

OLD LEAVES REVEAL BOUNDARIES

The CO₂ boundary, which controls the climate, was established by probing into the variation of the concentration in the

atmosphere during the 12,000-year-long Holocene. The CO₂ level can be studied in ice cores drilled from glaciers in Greenland and Antarctica and by observing air bubbles in the ice. Thousand-year-old leaves from birch and willow trees preserved in bogs can also reveal the concentration. Leaves absorb CO₂ through guard cells. The less CO₂ in the air, the more guard cells. By finding leaves, dating them, and counting the number of guard cells, the scientists established that the CO₂ concentration has varied relatively little during the Holocene: between 270 and 330 molecules per million (ppm). In 2015, the level had increased to 400+ ppm, rising about 2 ppm/year. According to the scientists, the boundary is 450 ppm. At that point, the atmosphere will contain so much CO₂ that the Holocene will end.

In connection with the other boundaries, scientists have taken a look at Earth's

66

We now consume some 35% of the 54 billion tonnes of plant material that the Earth produces annually on dry land (food, feed, power source)

resources – such as water, nutrients, and plants – comparing them to our consumption. Satellite images show that we now consume some 35% of the 54 billion t of plant material that Earth produces annually on dry land. We eat some of it in the shape of fruit and vegetables, and some is used to feed animals or burned in power stations. The 54 billion t is the upper boundary of the number of plants Earth can produce, and ►

4

Deforestation

Trees produce vital oxygen, which animals and humans breathe. But only some 62 % of Earth's original forests remain – the rest have been felled to make room for fields and

cities. If we lose any more forest, it could mean severe global warming. In order to remain in the green, the area must increase to 75 %, and farming must be reduced.



Huge Greenhouses in The Ground

To recover some space for Earth's forests, we must grow crops below the ground. The advantage of underground crops is that they only consume 1% of the space required by traditional farming, according to data from the world's biggest indoor vegetable grower, Mirai of Japan. In an abandoned Sony structure, 27,500 LED lamps make sure that Mirai can ship 10,000 crisp heads of lettuce a day. Several countries rely on underground greenhouses. Two factories are already operating in Mongolia, where it is difficult to get fresh vegetables in the winter. And in London, plants have moved into a World War II air-raid shelter. Energy-efficient LED bulbs make the greenhouses profitable and can be designed to emit light of optimal wavelengths.

Workers harvest lettuce in an 11-storey underground vegetable plant in Japan.

THE ASAHI SHIMBUN/GETTY IMAGES

PROBLEM
SOLVED!

5

Ozone layer depletion

The ozone layer is recovering, and the world is once again in the green area here at least. The ozone layer "fix" shows that, when we put our minds to it, we can solve these huge global problems.



% of the level before the breakdown began

Deodorant came close to killing all Life

30 years ago, a meteorologist discovered that the ozone layer above Antarctica had become 50 % thinner. The hole was growing, and world leaders had to act fast to save life on Earth from the burning sunlight.

Concern spread in 1985, when scientists realised the extent of the problem: Earth's ozone layer was breaking down, and soon, sunlight would burn our skin, harm ocean plankton, cause severe eye diseases, and destroy plants such as rice, which feeds major parts of Earth's population. Luckily, scientists soon found the cause of the growing ozone hole: chlorine from so-called CFC gases used in refrigerators and cooling systems and as a propellant gas in spray bottles.

The chlorine ends up in the atmospheric layer known as the stratosphere, which is located 10-50 km above Earth and contains the majority of the protective ozone. Scientists discovered that chlorine from

the spray gasses steals oxygen atoms from ozone, converting it into ordinary atmospheric oxygen, that cannot block out UV radiation.

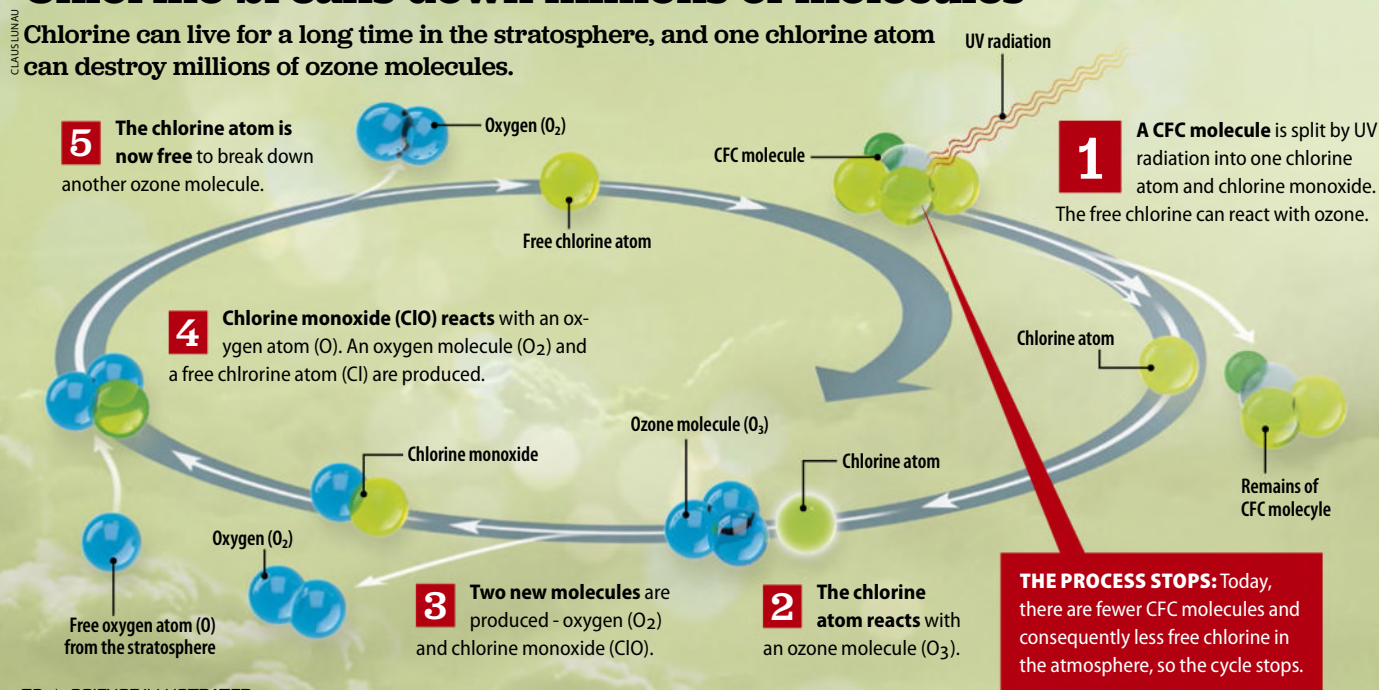
The breakdown of the ozone layer made the UN create the Montreal Protocol, which took effect in 1989, banning CFC gases. The agreement meant that the ozone layer hole stabilised in 2000.

However, chlorine atoms are tough, and 25 years passed before scientists concluded for the first time, in late 2014, that the huge hole in the ozone layer had shrunk. In 2003, UN secretary general Kofi Annan referred to the ban as "the perhaps most successful international agreement so far".



Chlorine breaks down millions of molecules

Chlorine can live for a long time in the stratosphere, and one chlorine atom can destroy millions of ozone molecules.

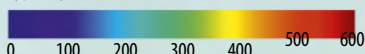


SUCCESS:

The hole was mended

The ozone hole is located above Antarctica. If it had developed above populated regions, it would have been disastrous. In 1989, a group of ozone-destroying gases were banned, and the hole stabilised. Scientists expect the hole to shrink further in the future.

Ozone layer thickness is measured in Dobson units, typically 0-600. The thicker, the better.



■ Little or no ozone

■ Very thick ozone layer

1979

1989

2014

2050

IT COULD
HAVE BEEN
THIS BAD

HOLE SHOCKS SCIENTISTS

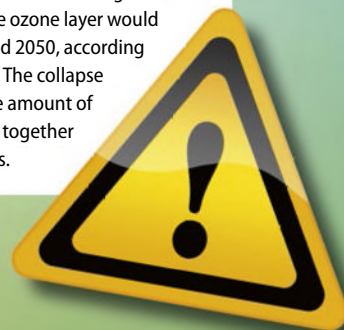
The ozone layer above Antarctica is gone. Some coolant gases are banned to reverse the terrifying development.

RECOVERING OZONE LAYER

The ban on the use of cooling agents means that the ozone layer shows signs of recovery for the very first time.

NO OZONE IN 35 YEARS

If the coolant agents had not been banned, the hole in the ozone layer would have grown further, and the entire ozone layer would have collapsed around 2050, according to NASA calculations. The collapse would have made the amount of UV radiation explode together with skin cancer cases.



New gases are harmful

When the so-called CFC gases were banned, the industrial sector developed replacements known as HFC gases, which boast about the same capacities, but do not harm the ozone layer. However, it now turns out that so-called VSLs chemicals, short for very short-lived substances, are probably also depleting the ozone layer. Today, 90 % of the VSLs chemicals in the atmosphere derive from natural sources such as algae, but industry is also responsible for some, such as methylene chloride. Methylene chloride emissions increased by 20 % in 2012-2013. The gas is produced when HFC gases are manufactured. Methylene chloride is not yet included in the Montreal

Protocol, but it probably will be in the next review.

SHUTTERSTOCK

6

Ocean Acidification

About 25 % of all CO₂ emitted into the atmosphere is absorbed by the ocean, making it acidic. Molluscs and corals cannot grow shells in acid water, as the calcium

cannot be bound in the water, resulting in less free carbonate ions, which are essential to grow shells. Without shells, the creatures die, disrupting the entire food chain.



% of the ocean's original concentration of carbonate ions

Clean smoke, please!

A lot of the carbon dioxide that we emit is absorbed by the ocean, making the water more acid, so the CO₂ must be captured.

Imagine the whole ocean as a Soda Stream machine. That is about how the situation in the seas can be described – apart from carbon dioxide oozing into the water without the help of machines.

Carbon dioxide, CO₂, which we add to mineral water, makes the oceans more acid, and since the early industrial era, the pH value of the oceans has fallen from 8.2 to 8.1, and between now and 2100, scientists expect the pH to fall to 7.8 (lower is more acidic). To prevent disaster, the CO₂ must be captured, before it escapes, for instance, power station chimneys. The most promising technological solution is so-called adsorption, by which the CO₂-rich smoke passes through a porous material

with a large surface, capturing CO₂. Some materials can be purified and reused by means of pressure or heat, whereas others are buried, once they are full. In early 2015, a scientist from the New Mexico State University, Nasser Khazeni, patented a material which can capture CO₂ 100 times more efficiently than any other. When the CO₂ has been isolated, it can be pumped into underground stores, and perhaps used later.

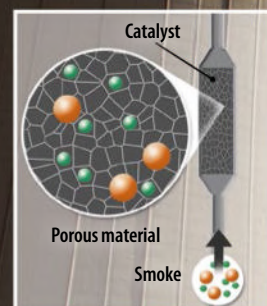
However, geologists warn that CO₂ storage increases the risk of earthquakes, as the large amounts of CO₂ put pressure on Earth's crust from below.

SOLUTION 1

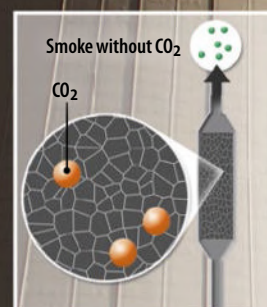
Efficient material captures CO₂

A new composite material binds carbon dioxide in smoke 100 more efficiently than similar materials.

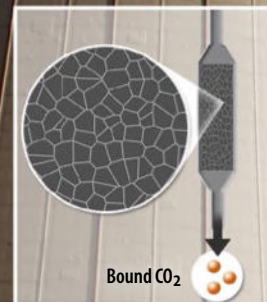
1 Exhaust or smoke is directed through a catalyst, which contains a porous material that can bind CO₂, such as minerals of the zeolite type.



2 Other gases in the smoke are forced out at the top of the catalyst under high pressure. CO₂ remains bound in the material.



3 The pressure in the catalyst is reduced, and the material lets go of the bound CO₂ at the bottom of the cylinder. The CO₂ is collected in a container, and the catalyst is ready to purify new smoke.



SOLUTION 2

Strong base neutralizes acid

Carbon dioxide from the air oozes into the ocean, making it more acid. The acidity effect can be neutralised by adding a base, so the ocean water remains weakly alkaline.

But according to a study from the University of Hawaii, a base is probably not a durable solution for both practical and financial reasons.

The neutralisation will require that we pour 100 billion tonnes of calcium oxide into the ocean annually to keep the acidity level constant. Such an amount assumes that CO₂ emissions continue at the current level and do not increase.

Also, it would cost not billions, but trillions of American dollars.

► so, we must adjust our needs accordingly.

RISKY COCKTAIL

Scientists quickly discovered that the nine systems cooperate and affect each other. Changes in one system accelerate change in another. Deforestation makes climate change worse, as forests absorb CO₂ from the atmosphere, binding carbon. And when temperatures rise, much more water evaporates from fields and forests, increasing the need for irrigation. Another cocktail is found in nutrient and air pollution: Only 10-15 % of the nitrogen "fed" to fields actually contributes to food production. 85-90 % ends up in nature,

where the materials are harmful. Nitrogen can also form part of smog particles or end up as toxin such as nitric acid in lakes, killing fish and insects. Moreover, nitrogen can be included in gases, aggravating the greenhouse effect by holding on to atmospheric heat.

However, the cocktail effect could also be an advantage, as improvement of one system affects others. If forests grow, it will have a positive effect on climate change, although CO₂ emissions from traffic, industry, and energy production continue at the same rate.

LIKE 1,500 PLANE CRASHES A DAY

Based on the results of sophisticated computer models, scientists have created a green-yellow-red danger indicator to describe the health of the systems.

Boundaries have been determined based on risk assessment of when the systems will tilt. With the present concentration of greenhouse gases in the atmosphere, the risk of a temperature rise of 6 °C is 1.6% – enough to end the Holocene.

"Most people would say that a risk of 1.6 % is not frightening – we can live with that. But compared to flight safety, a risk of 1.6 % would be 1,500 plane crashes a day," Richardson points out.

ALGAE BENEFIT FROM POLLUTION

Moreover, harm to the systems is not easy to correct, but over a short period of time, less irrigation could re-establish the natural water levels of rivers and lakes.

But it would take many years to correct the negative effects of fertilisers such as phosphorus and nitrogen. Once the fertilisers are present in the aquatic environment, they will cause severe algae growth. The algae die and are converted by microorganisms, and the nutrients are released back into the water. In fresh water, phosphorus is the biggest problem, but in the ocean, nitrogen plays a bigger role in environmental change.

The problem is not just the amount of nutrients, but also the distribution. Nitrogen carried by the Mississippi River causes a dead zone in the Gulf of Mexico. There, the concentration of nitrogen is so high that ►

7

A Mass Extinction

The world's animal and plant species are going extinct some 1,000 times faster than before humans conquered Earth, and if nothing is done, in only 900 years higher life will

be gone. One of the causes of the fast extinction rate is that we have turned nature into a system of cities and roads. Animals are cut off and cannot find new mates.



Number of extinct individuals per year per million species

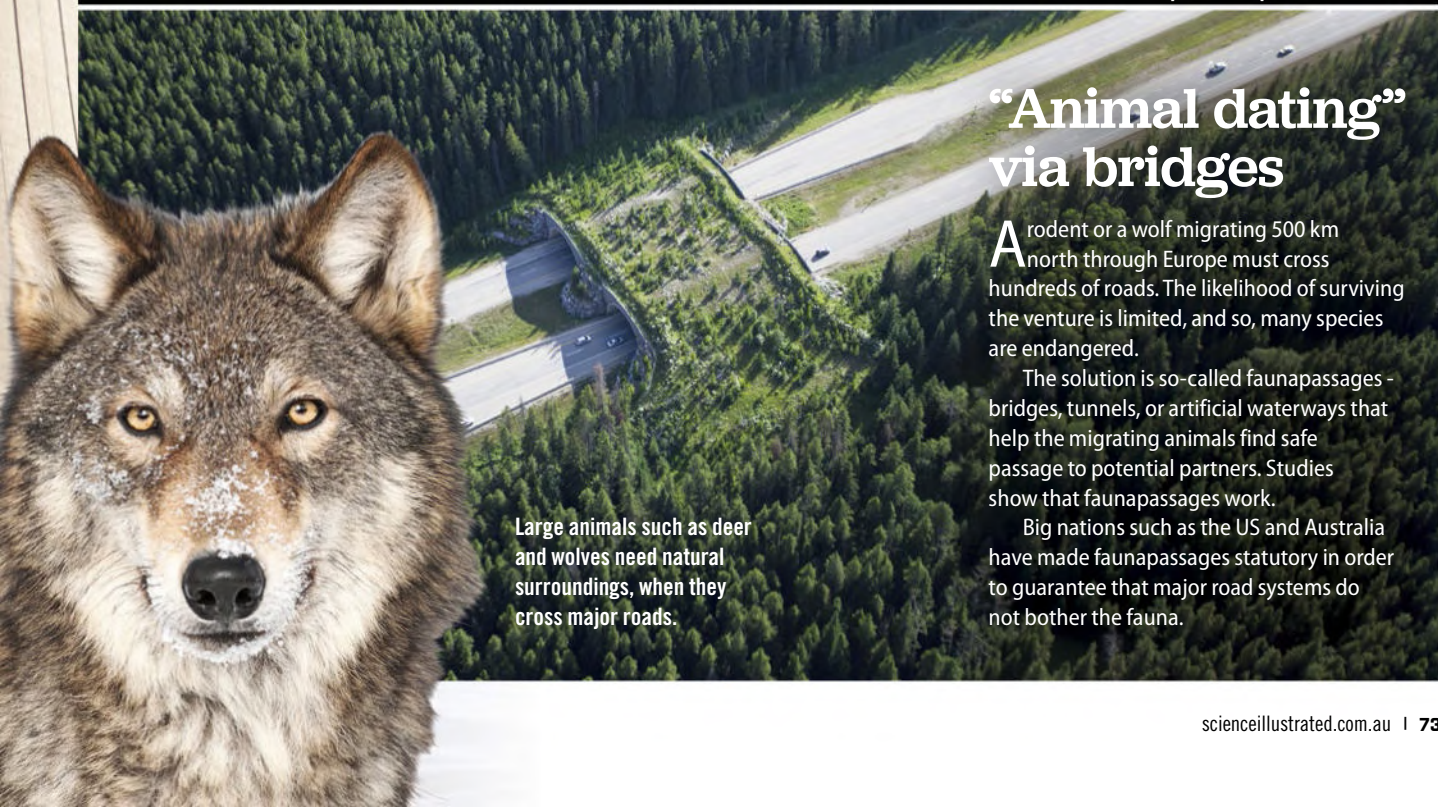
"Animal dating" via bridges

A rodent or a wolf migrating 500 km north through Europe must cross hundreds of roads. The likelihood of surviving the venture is limited, and so, many species are endangered.

The solution is so-called faunapassages – bridges, tunnels, or artificial waterways that help the migrating animals find safe passage to potential partners. Studies show that faunapassages work.

Big nations such as the US and Australia have made faunapassages statutory in order to guarantee that major road systems do not bother the fauna.

Large animals such as deer and wolves need natural surroundings, when they cross major roads.



► almost no animals remain. Conversely, major parts of Africa desperately need nitrogen and phosphorus.

CHEMISTRY AND GENE MANIPULATION

In connection with two of the nine vital systems, scientists have been unable to establish sensible boundaries, as their knowledge is too limited. What they do know is that genetically modified plants and bacteria can out-compete and exterminate natural species. So, GMOs are considered a threat to Earth. The boundaries of plastic and air pollution are also still unknown.

But several examples warn us that artificial substances could have a severe effect on the environment and health. In the US, GM plants have killed millions of caterpillars. Hormone-like substances in food cause deformed genitals in boys, and hormones in drinking water change animal behaviour and limit their ability to reproduce. The solution is to limit the amount of artificial

substances in the environment and make sure that the systems will not get out of control. Scientists are developing a method to supply GM plants with a safety device, so they will automatically wither and die without specific, man-made nutrients.

SPACE MIRRORS AREN'T A SOLUTION

Eight of the 9 nine vital systems have one thing in common: they are heading in the wrong direction – even the ones that are still in the green area.

The only bright spot is the ozone layer. At the worst point, the danger indicator was in the yellow area, but a united international effort stopped the breakdown: The ozone-destroying substances were banned internationally, and industry developed new and less harmful alternatives.

The solutions to Earth's problems are many, but generally, treating symptoms is a bad idea. One suggested solution is placing huge mirrors in space, which could reflect

sunlight, cooling the atmosphere. But the mirrors do not solve the central problem: the emission of greenhouse gases. Other suggested solutions will solve the problem. A long-lasting solution to Earth's space problems could be growing vegetables below the ground or in high-rises to make room for animals and forests. And garden owners can help increase the forest areas by replacing their lawns with trees, bushes, and flowers. But make no mistake: we need to act now, in a real way. **SC**



8

Lack of fresh water poses a threat

Every year, the people of the world consume 2,600,000 billion litres of fresh water (2,600 km³), corresponding to all the water of Lake Victoria in Africa. So far, the consumption is

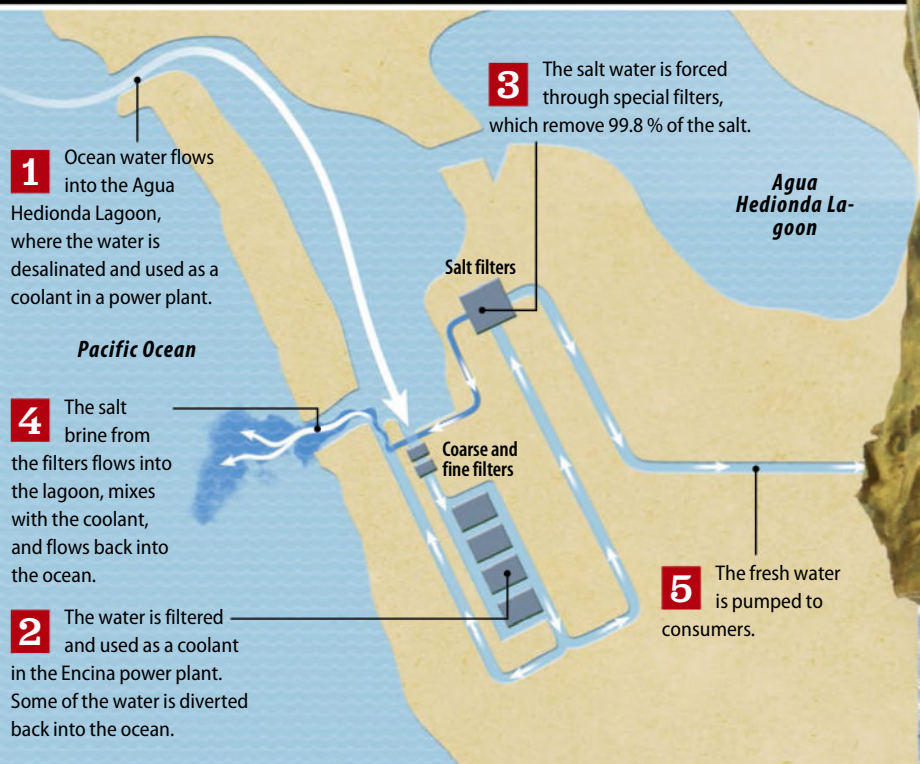
not critical for the world as a whole, but in some places, there is severe water shortage. As the world population grows, lakes and groundwater sources will not be enough.



Just drink ocean water

Fresh water is scarce, and so, several plants are ready to desalinate ocean water throughout the world. In 2016, the biggest desalination plant in the western hemisphere opens in drought-stricken California. The Carlsbad Desalination Plant can produce almost 200 million litres of water per day. The state of California is desperate, as calculations show that the region's fresh water reserves will soon be depleted. The last litre will probably be consumed on the day the plant opens.

So far, dry areas are more severely affected by water shortage, but desalination is energy-intensive and expensive: A plant such as Carlsbad costs \$1.4 billion to build, but as solar and wind power become cheaper, the price of desalinated ocean water will fall.



9

Plastic and GMOs clogging the ecosystem

In recent centuries, we have invented hundreds of thousands of amazing new substances and adjusted plants and bacteria according to our needs. Often, we have no

idea of the environmental effect. According to scientists, we could be facing a disaster, if some of the organisms mutate, or if plastic pollution does not stop.



An integrated mechanism can force plants to die, so they will not spread.

SHUTTERSTOCK

A plant's built-in kill switch

SOLUTION 1

In an effort to control GM plants, biologists have included a suicide mechanism, so the plants will die without artificial nutrients.

Genetically modified organisms, GMOs, could be a major part of the solution to Earth's problems. Crops could be designed to consume less water or fertiliser, and bacteria could be modified to produce medication or washing enzymes or to remove pollution.

But GMOs also cause problems, when they escape into nature. GM plants could out-compete natural species, and bacteria with optimised genes could share them with bacteria that make us sick. However, scientists have found an

innovative solution to the problem by inserting genes that make the organism dependent on an artificial amino acid in the organism's genetic material.

Amino acids are the basic building blocks of proteins, and without the artificial amino acid, the organism will die. The trick is like the safety device of a train engine, which the driver must activate regularly, or the train stops by itself. So far, the method only functions with bacteria, but scientists expect to be able to transfer it to plants and animals within a few years.

Huge arrays vacuum the ocean

Would you like to eat a LEGO brick? Probably not, but nevertheless, tiny bits of plastic end up in the stomachs of birds, in fish scales, and finally in our food. Plastic must be removed from nature, if it is not to end up as a pollutant in the food chain. But how?

In 2012, a 17-year-old Dutch boy, Boyan Slat, came up with a brilliant solution to the problem. He suggested a system of floating barriers anchored to the ocean floor at the centres of the circular,

mid-ocean currents. In 2014, Slat carried out a huge pilot experiment in the ocean off the Azores. The results showed that the system can "clean" an ocean current in 5-10 years. The method is so efficient that it is cheaper than banning the use of plastics altogether.

SOLUTION 2

New experiments in the ocean off the Azores showed that in 10 years, huge arrays could collect 42 % of all plastic in the Pacific.

OCEAN CLEANUP

5 August
1888

127 years ago, Bertha Benz went for her first ride in a petrol powered car: a trip that would change the world.

DAIMLER AG - GLOBAL COMMUNICATION



◀ Past and ...

How Mrs Benz Made Cars Work For the Rest of Us

When Carl Benz built a car and started selling it to rich, idle people who liked expensive toys, almost nobody thought the eccentric invention had the power to change the world. But Benz's wife Bertha saw the car's potential... and one day she went for a drive to prove it.

By Andreas Ebbsen Jensen

The Sun has just risen above the German city of Mannheim, and Bertha Benz is wide awake. On the other side of the bed, her husband, the inventor Carl Benz, is sleeping heavily. For years, he has worked hard to construct the world's first petrol-powered vehicle, and now, the three-wheeled automobile he calls the Patent-Motorwagen No. 3 has finally been completed. However, Carl Benz finds it difficult to take the last step, bringing his ground-breaking invention into production. A couple of failed test drives have made Carl Benz doubt his own project, and what's worse, he has no head for business whatsoever.

But Bertha Benz is not in doubt: Her husband's petrol-powered vehicle is a rising star – and it is about time that the rest of the world realised it and, not least, benefitted from the invention. Together with her two teenage sons, she sneaks into the garage, and while Carl Benz is still dreaming, the three-wheeled automobile conquers the dust-laden German country roads on 5 August 1888 with Bertha Benz in the driver's seat and the couple's two boys in the back seat.

STOCKINGS REPAIR EXHAUST SYSTEM

Bertha Benz' plan is as ambitious as it is risky. She intends to drive 100 km cross-country to visit her parents in the city of Pforzheim and put the automobile to the ultimate test. At this time, Carl Benz' invention has only driven a few kilometres at a time, but his wife thinks it can do much better than that. However, the pioneering tour is not trouble-free.

The first challenge arises, when the automobile runs out of fuel after travelling

just 50 kilometres. The dynamic woman remains calm and stops at a local pharmacy to fuel the car with ligroin, also known as petroleum ether. Later, the exhaust system starts to fail, but luckily, Bertha Benz has spent many hours in the garage with her husband, so she repairs it by insulating the exhaust pipe with one of her stockings.

Bertha Benz is also the woman behind the world's first brake pedals, as on her way to Pforzheim, she instructs a shoemaker to replace the car's worn-out wooden pedals with shoe soles.

EXPLOSIVE SALES

Bertha Benz' strong will and belief in her husband's invention pays off, and as the sun sets on Pforzheim, Bertha Benz and her two sons arrive at her parents' house. The rumour of her wild stunt has already reached the small garage back home in Mannheim. Germans rarely witness a petrol-powered vehicle drive through the landscape – with a woman behind the wheel. Several eyewitnesses tell the press the incredible story about Bertha Benz' pioneering tour.

The historic trip gets all the attention that Bertha Benz had



Bertha Benz' two sons push-started the car with their mother, and joined her on the historic first trip (this photo is a reconstruction).

Present ▶

Ghost cars: no hands on the steering wheel

The biggest car makers in the world such as Toyota, Renault, Daimler, and Volvo have entered a fierce race to introduce the first autonomous car. However, they need to

step on the gas, if they do not wish to be outdistanced by Google. The IT giant plans to introduce the first driverless cars in 2020 – a wake up call for everyone else.

hoped it would. The Benz family's ground-breaking invention quickly becomes the subject of conversation in Germany and abroad, and 10 years later, Carl Benz' small garage has grown into the world's biggest car maker with 400 employees and selling 600 automobiles per year.

Moreover, once the engine had been invented, it was also placed in planes, ships, etc., contributing to making the world a smaller place. **SC**

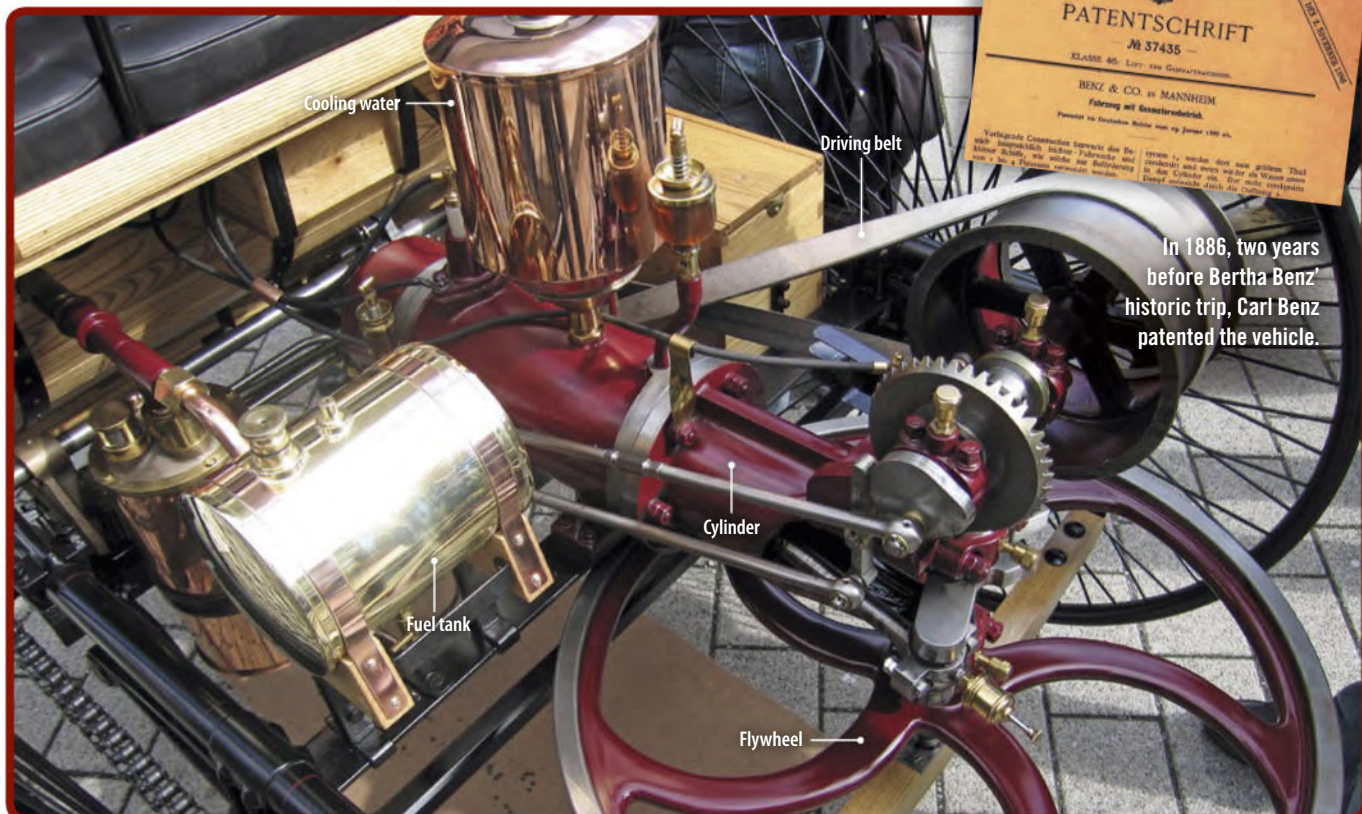
According to Carl Benz (above right), Bertha (above left) was the only person who believed in him and his automobile project.



The car was as "fast" as a bike

The Patent-Motorwagen No. 3 had three wheels and a rear-mounted, two-stroke engine placed between the seats. The petrol-powered, single-cylinder engine weighed 100 kg and put out 1.1 hp at 400 rpm, boasting a maximum speed of 16 km/h. The transmission, a far cry from modern 7 or 8-speed automatics, had one gear and consisted of a simple belt drive.

DETAIL



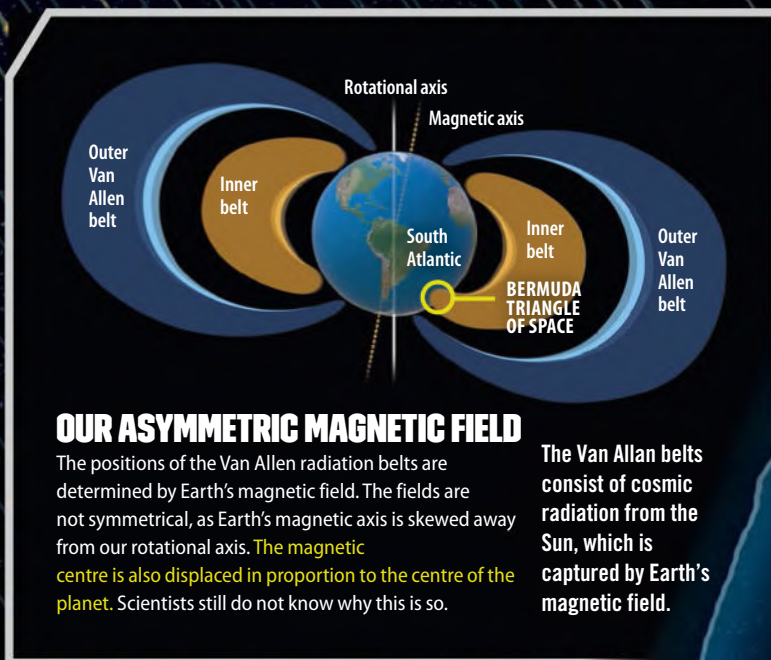
In 1886, two years before Bertha Benz' historic trip, Carl Benz patented the vehicle.

A BERMUDA TRIANGLE IN SPACE

Earth's magnetic field protects us against radiation from space, but above the South Atlantic, there is a hole in the shield. The radiation is so intense there that **astronauts experience visual disturbance, the Hubble telescope shuts down, and satellites fall into a coma.** Scientists fear that the phenomenon is the first warning that the vital magnetic field is crumbling.

By Niels Hansen. Art: Claus Lunau

Earth's magnetic field



Shortly after its launch on 25 September 2010, the American SBSS satellite sent an SOS. The billion-dollar spacecraft was in trouble above the South Atlantic Ocean. The satellite was so badly affected by cosmic radiation that a computer component failed. According to plan, the SBSS was to monitor space junk after a short test period. But instead, engineers on Earth had to spend two years developing a software update that could fix the half-fried satellite.

HUBBLE CLOSES ITS EYES

The SBSS was zapped in the South Atlantic Anomaly (SAA). There, in the "Bermuda Triangle of space", Earth's magnetic field is about 30% weaker than elsewhere, allowing the innermost of Earth's two Van Allen belts to move close to Earth.

RADIATION CRASHES THROUGH THE SHIELD

Above the South Atlantic, off the coast of South America, Earth's magnetic field is weak, so electrically charged cosmic radiation can pass through its protective armour.

Particles destroy chemical bindings

The radiation from the Van Allen belts is hazardous to both computers and living creatures. The particles can destroy chemical bindings, alter molecular structures, and accumulate static electricity.

Weak field produces the Bermuda Triangle of space

Above the South Atlantic, Earth's magnetic field is weak, and radiation from the Van Allen belts is not blocked.

A satellite swarm studies weakened space shield

This weak spot probably keeps growing due to changes in Earth's magnetic field. The three Swarm satellites are to measure the field very accurately, allowing us to predict developments.

South Atlantic

The Van Allen belts consist of high-energy particles from space that speed about each other. In the SAA, even small satellites are hit by 20 million high-energy particles per second. The radiation is so intense that it can easily cause errors in spacecraft computer systems, and in the rare event of astronauts taking space walks there, they experience strange visual effects from the bombardment.

Most of the about 500 satellites orbiting a few hundred kilometres above Earth – in Low Earth Orbit – have integrated defence mechanisms that are activated in the hostile environment above the South Atlantic. The Hubble space telescope shuts its most vulnerable sensors down when it passes through the area. But the problems are

growing, as the more sophisticated satellite electronics get, the more vulnerable they are to radiation.

WARNING OF WEAKENED FIELD

Moreover, the Bermuda Triangle of space is growing slightly, and satellites need to shut down for longer periods of time.

Scientists consider the growing SAA a sign of a general weakening of Earth's magnetic field. Measurements indicate that the field has lost 10-15 % of its strength in only 150 years. Geologically speaking, that is an extremely rapid pace, and we don't yet have an explanation for why it's happening.

So, the Swarm Mission was launched in 2013. Swarm consists of three satellites orbiting in a special formation which

produces the most accurate measurements of the magnetic field and the processes in Earth's interior that gives the field its shape and strength.

One of the scenarios investigated by Swarm is whether the SAA is the first warning of a future pole reversal. Such reversals take place at intervals of several hundred thousand years, so the risk is minimal. The latest pole reversal happened 780,000 years ago, but if it took place now, it would cause a huge disaster. During the period, in which the poles change places, Earth's magnetic field is nonexistent, and more cosmic radiation could reach Earth's surface, possibly destroying all electronics, shifting the ecological balance, and threatening our existence. **SC**

TRIVIA

PUT YOUR KNOWLEDGE
TO THE TEST

1. How many times a second does lightning occur on Earth?
2. Meaning "highest city", what is the name of the famous ruined temple complex in Athens, Greece?
3. What are the Aventine, Caelian, Capitoline, Esquiline, Palatine, Quirinal and Viminal?
4. Where do you have to go to visit Cthulhu Regio?
5. Why does Koenigsegg call its latest supercar the "One:1"?
6. Now grounded until 2016, what was the Solar Impulse attempting to do this year?
7. In 1929, what did Harold Bell Lasseter claim to have found at the edge of the MacDonnell Ranges in WA, in 1897 or 1911?
8. What David Bowie song did astronaut Chris Hadfield film himself singing on board the ISS in May 2013?
9. Which Australian city was hit by a 5.9 Richter earthquake on 28 December, 1989?
10. Which Australian "boats" are named Farncomb, Waller, Dechaineux, Sheean, Rankin and Collins?

ANSWERS ON p82!

q. 1



q. 8

Trivia Countdown (use fewer clues, get a higher score!)

	5 POINTS	4 POINTS	3 POINTS	2 POINTS	1 POINT
1. ARCHAEOLOGY Name this ancient city	The city was founded by the Ammonites on the banks of the river Tigris in what is now Iraq in 1894 BCE	The citizens had a flair for math, laying the foundations of algebra, fractions, and the Pythagorean theorem.	At one point, the city was the capital of the Persian Empire, and Alexander the Great died there.	The ancient city was once famous for its hanging gardens, one of the 7 wonders of the world.	According to the Old Testament, the Tower of Babel was built in the city, and inspired the name of the city.
2. HISTORY Name this war	The use of machine guns and mechanical transport earned it a status as the first modern war.	The war was fought in 1861-1865. 850,000 soldiers are estimated to have been killed in the fighting.	On one side were "yankees" in blue uniforms. On the other, rich, white farmers wearing grey attire.	The war is said to have been caused by disagreement concerning slaves, but several factors played a role.	Abraham Lincoln was the president of one of the parties. Jefferson Davis was the president of the other side.
3. SPORTS Name this game	Earl Anthony, Parker Bohn III, and Dick Weber are among the best players of all times.	Different versions of the game have existed for 5,000+ years. It is played on a 105-cm-wide, 18-m-long track.	The maximum number of points to be earned during a game of 10 frames is 300.	A strike will earn you the most points. The second best throw is known as a spare.	The game is about throwing a heavy ball towards 10 pins, trying to knock over as many of them as possible.

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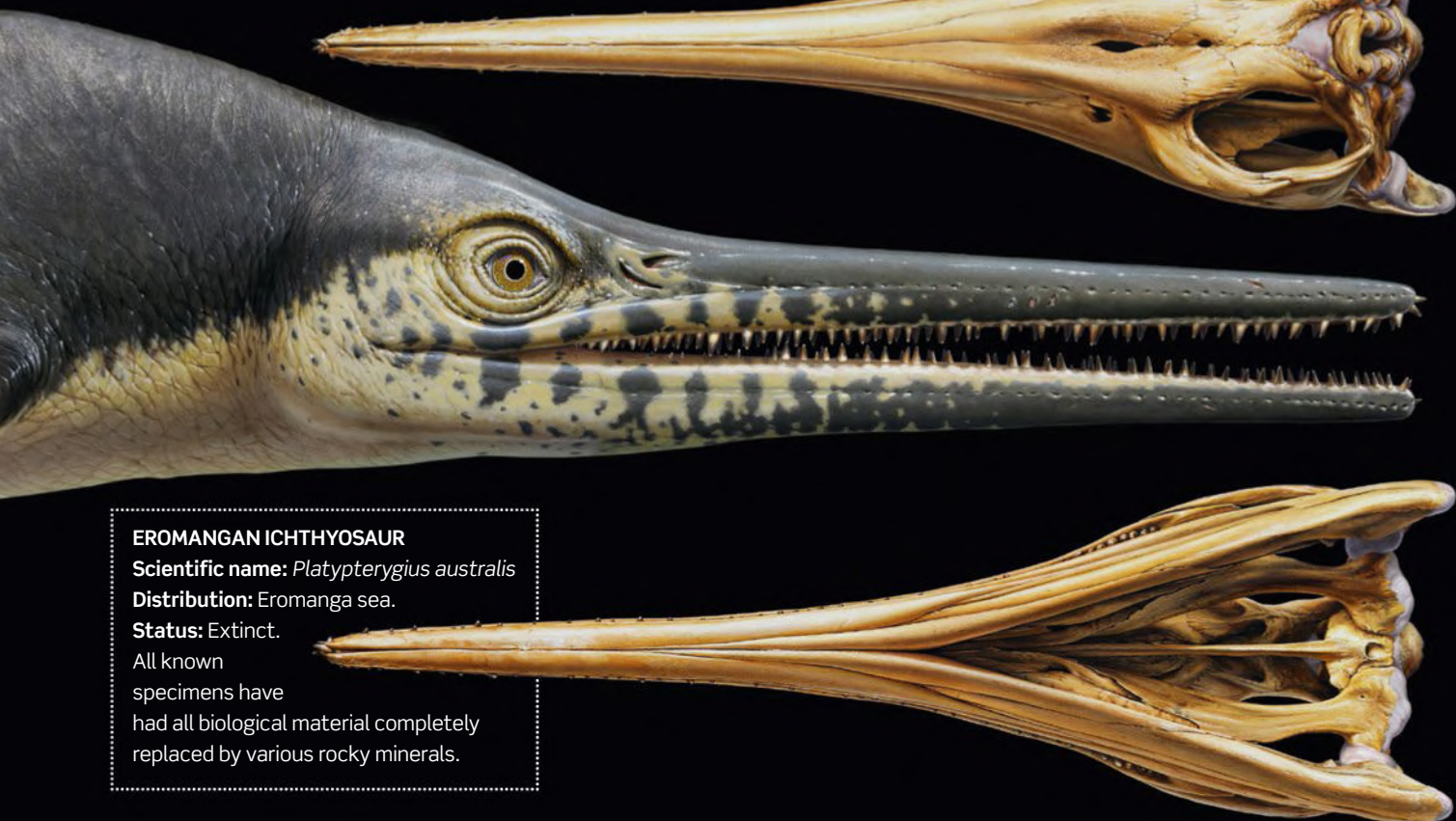
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**EROMANGAN ICHTHYOSAUR****Scientific name:** *Platypterygius australis***Distribution:** Eromanga sea.**Status:** Extinct.

All known specimens have had all biological material completely replaced by various rocky minerals.

BEASTS FROM AN ANCIENT SEA

Because so many NSW rivers flow inland, early European explorers spent decades believing in and trying to find a vast inland sea that doesn't - as we know now - exist. But it turns out those explorers were right about the sea. They were born just a bit too late to find it. About 120 million years too late.

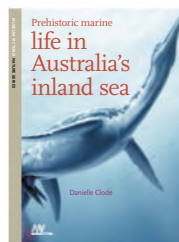
In the Cretaceous period, the landmass that became Australia was flooded by a cool, shallow sea named after a modern region called Eromanga (the word means "hot gale plain" in an unknown Aboriginal language).

Fossil evidence shows us that the Eromanga was home to a bewildering variety of ancient animals. Plesiosaurs were bountiful, and at least two became beautiful opalised skeletons that you can see

in the South Australian museum and the Australian Museum in Sydney.

The creature shown here in both its fossil form and in reconstruction is an ichthyosaur, specifically *Platypterygius australis*. In the same way dolphins look like fish but are actually mammals, ichthyosaurs are actually classed as reptiles (further study may change this, but for now, they are reptiles).

Unlike dolphins though, ichthyosaurs probably used extremely acute vision rather than echolocation to hunt prey - they have the largest eye of any animal so far discovered, with some fossils indicating an eye 25 cm or more in diameter.



For more on Aussie ichthyosaurs, plesiosaurs and others, pick up a copy of Museum Victoria's *Prehistoric Marine Life in Australia's Inland Sea*, available now. Or **subscribe on page 62** for your chance to win a copy!

P. australis grew to five metres and had large fins built for cruising the waters of the Eromanga. Crucially, it's likely the animal also had warm blood - important in a world going through a series of bitter ice ages.

It's amazing to think that the biodiversity we take for granted in Australia today is merely the tip of a vast iceberg of biological change going back millions of years. To a time, indeed, where actual icebergs floated in a sea that still haunted the dreams of humans millions of years later. **SCI**

TRIVIA ANSWERS: 1. 40-50. 2. The Acropolis. 3. The Seven Hills of Rome. 4. Pluto. 5. Its power-to-weight ratio is one horsepower per one kilo. 6. Fly around the world on solar power only. 7. A massive gold deposit (Lasseter's Reef). 8. Space Oddity. 9. Newcastle, NSW. 10. The Collins-class submarines. **Trivia Countdown:** Name this ancient city: Babylon. Name this war: The American Civil War. Name this Game: Ten-Pin Bowling

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